ADAPTING AGRONOMIC TECHNOLOGY FOR SMALL FARM BEAN PRODUCTION IN HIGHLAND COLOMBIA

By

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A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

University of Florida
1978

DEDICATION

This dissertation is dedicated to those agronomists of all nationalities who believe that technology can improve the lives of the peasant agrarian populations in the less-developed countries. Throughout history, mankind has looked to agronomy for sustenance, but rapid technological advancements have changed the nature of the science, placing more importance on production statistics than on the well-being of the world's farmers. To reverse this situation, a new generation of activists is needed, believers that in agronomy lie many of the answers to the socioeconomic problems of the Third World.

ACKNOWLEDGMENTS

Of the many people who contributed to this study, two individuals, Dr. Darell McCloud and Dr. Charles Francis, deserve special recognition. Dr. McCloud served as chairman of the supervisory committee and helped create an academic environment conducive to the author's individual development. The exceptional dedication, enthusiasm and compassion of Dr. Francis earned him the deepest respect from Latin American and North American co-workers and set a high standard for the author to follow. However, this study would not have been attempted without the encouragement many years earlier of Dr. G.O. Mott and Dr. John Bishop that one should apply himself to the problem he perceives as critical and most relevant, regardless of how complex and hopeless the problem may appear on the surface or how unconventional may be the approach.

Appreciation is also extended to Dr. Hugh Popenoe, Dr. Paul Doughty, Dr. Victor Green, and Dr. Allan Norden for serving as members on the supervisory committee, and to Dr. William Duncan for editing an earlier draft of this dissertation. The funding for this study, which was provided by the Center for Tropical Agriculture and the *Centro Internacional de Agricultura Tropical* (CIAT), and the support and assistance of Dr. John Nickel, Dr. Kenneth Rachie, Dr. Fernando Fernandez, Dr. Douglas Laing, Dr. Aart van Schoonhoven, Dr. Oswaldo Voysest, and Dr. John Sanders along with many members of the CIAT staff are gratefully acknowledged.

The friendship and excellent cooperation of Oswaldo Renteria, regional director of the *Federacion Nacional de Cafeteros de Colombia,* and Julio Henao, of the ABOCOL fertilizer company were fundamental to the success of this study. Several other Colombians contributed their time and energy beyond the call of duty to the field research. To Julio Suaza and Orlando Herrera, Ing. Martin Prager, Ing. Fernando Takagami, Pedro Quevedo, Delio Arias, Robertulio Garcia, Alberto Cadavid, Sergio Antia, and Hover Carlosama, the author is especially indebted. The many ideas, constructive criticisms, and helpful insights of Ing. Carlos Flor were influential in formulating the research methodology and merit a special thanks.

This list would not be complete without some mention of the Colombian small farmers who willingly volunteered the land and information on which this study is based. Outstanding among them are: Raimundo Belalcazar, Libardo Salazar, Pedro Guerrero, Guermillo Spyta, Camilo Erazo and Luis Zuluaga.

And finally, let is be acknowledged in print, that my wife, Barbara, actively participated in every phase of this project, provided a source of strength when mine failed, and encouraged me forward toward the realization of my most idealistic goals. For this, above all, I am sincerely grateful.

TABLE OF CONTENTS

Page

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

Abstract of Dissertation Presented to the Graduate Council
of the University of Florida in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

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June 1978

Chairman: Dr. Darell E. McCloud
Major Department: Agronomy

Although it is widely accepted that rapid and significant increases in the food production of less-developed countries are possible through the application of capital-intensive agricultural technology to large commercial farms, economic and social development can only be achieved by improving the productivity and well-being of the peasant farmer. In the Latin American tropics, where approximately half of the population is employed in agriculture, 70% of the farms are less than 10 hectares in size. These small farms supply most of the staple food crops necessary to feed a growing population (3.1% per year), while large farms focus on export and industrial crops. High input, monoculture technology has not trickled down to Latin America's small farmers, because it is incompatible with their mixed cropping, low-risk production systems. Integrated Rural Development Projects, such as the Plan Puebla in Mexico, are slow, expensive, and site specific. Therefore, this

study was conducted to explore and evaluate a methodology which, with certain modifications, could be used to validate, select, and transfer agronomic technology to rapidly increase small farm productivity.

The objective of this 22-month study was to increase bean (*Phaseolus vulgaris* L.) yields and net returns on small coffee farms in a project area, which encompassed 16 villages around the town of Restrepo in the *Departamento del Valle del Cauca*, Colombia. The conceptual framework consisted of a phased series of on-farm experiments in an atmosphere of inter-institutional collaboration between a research institute (CIAT), a technical assistance agency (the Colombian National Federation of Coffee Growers), and the private industrial sector (represented by the ABOCOL fertilizer company). The three component phases of the methodology concerned the observation of the traditional bean production system, the design of a technological package, and the economic evaluation of this package at the farm level. The design phase was sub-divided into two segments, one for screening varieties from the CIAT world collection of bean germplasm, and the second for determining the major limiting factors of the production environment. In all, eight experiments were conducted on 61 farms in four seasons.

Farmer participation in the study was an integral part of the methodology. In an attempt to establish credibility with the farmers and to break down the obstacle of perceived risk, small farmers planted and managed variety comparison, limiting factor, and economic evaluation trials on their own farms, with each farm serving as a replication of the regional experiment. CIAT and ABOCOL supplied the necessary inputs and Coffee Federation extension personnel provided technical

supervision. Field days were held at the end of each season to present the research results to farmers who did not directly participate in the field trials.

This combination of research and extension in the validation of technology for small farms emphasized maximizing economic returns and adoption potential, while minimizing the number of changes in the traditional production system and the excessive use of expensive agrochemical inputs. The result was a low-cost, low-risk technology that significantly increased bean production (30%) and net income (54%). The final product was a generalized core technology that could be customized according to the specific microclimate and soil conditions of each farm and the financial means of the individual farmer. Although small farmers in Colombian coffee-growing regions have a socioeconomic importance that affords them more political attention than would be given to subsistence level small farmers, the results of this study suggest that technology can be modified to be both productive and profitable on small farms given an appropriate research-extension methodology. Since the final technology must be within the resource and risk aversion capabilities of small farmers, on-farm experimentation and farmer participation are essential.

INTRODUCTION

Perhaps the most significant landmark in the evolution of economic development theory to emerge from the 1970's is the sudden awareness of the importance of new agricultural technology in the solution of the small farm problem in less-developed countries. The role of agriculture in previously orthodox development theories (Higgins, 1959; Hirschmann, 1959; Johnston and Mellor, 1961; Schumpeter, 1961; Ramis and Fei, 1961; Eicher and Witt, 1964) was to generate surpluses to feed the industrial sector and to create a market for the products manufactured by local industry. This thinking was based on the history of economic growth in the more developed, capitalistic countries, in which the urban industrial labor force grew out of the dissolution of small family farms. Development was therefore expected to involve a staged, socioeconomic, structural transformation with a reallocation of labor from low-productivity traditional agriculture to high-productivity industry (Rostow, 1964). In this process, agriculture was to become more capital intensive and based on large scale units.

According to these theories, economic development could be monitored by annual growth rate of the gross national product of the individual countries. However, in spite of unprecedented increases in the gross national product of many less-developed countries during the 1960's, income disparities and absolute poverty also increased sharply. Escalating population growth had intensified the low productivity of the

traditional agricultural sector, forcing a mass rural to urban migration by those seeking employment and material well-being. Aside from slowly strangling the urban support system, this added a political sense of urgency to the phased, long-term, national development plans.

The transfer of capital and industrial technology from developed to underdeveloped countries in which the infrastructure, institutions, and technical skills were inadequate for industrialization was slow, difficult, and ineffective. In addition, the realization of the comparative and perpetual disadvantage of less-developed countries for heavy industry in world trade coincided with a shifting public attitude toward the ecologically disruptive nature of industry and its consumption of non-renewable resources. It became painfully apparent that development by the urban-industrial model was no longer feasible. This resulted in a proliferation of modified development strategies with a rural-agricultural orientation (Schultz, 1964; Mosher, 1966; Mellor, 1969; Jorgenson, 1969; Hayami and Ruttan, 1971; Owen and Shaw, 1972).

Although forecasted deficits in world food supplies have fueled the interest and investment in expanded agricultural production, from a development standpoint the most important aspect of agriculture is its potential ability to improve the income of the rural poor. As farming becomes a more profitable enterprise there is a greater incentive to stay in agriculture. More lucrative employment opportunities in rural areas would diminish the rate of rural to urban migration, while higher rural incomes create a demand for non-agricultural consumer goods. However, these theoretical benefits depend on the ability of agricultural technology to increase yields on small farms.

In Latin America, agriculture is characterized by two distinct farming sectors. The large farm (*latifundio*) or modern sector generally provides the majority of the export crops, livestock, and the fiber and vegetable oil for domestic industry. These commercial farms typically occupy the lands best suited for agriculture, and function in response to national and international market conditions. Although *latifundios* are extensively rather than intensively exploited, they commonly utilize high capital input levels. In contrast, small farms (*minifundios*) represent the traditional agricultural sector, which occupies the more marginal, often mountainous, soils, and supplies staple food crops for domestic consumption. These two sectors differ not only in character, but also in relative potential for adopting agricultural technology.

Technology has historically been first applied to high value cash crops. In recent years, expanded agricultural production throughout Latin America has been due primarily to the introduction of agricultural technology from the developed countries to *latifundios*. These large farming units are similar to those for which the technology was originally designed. At the same time, the operators of these enterprises were receptive to technological advances, had ready access to credit, agro-chemicals, and marketing channels, and often possessed the necessary political leverage to maneuver policy decisions in their own best interests. *Latifundios* have a clear comparative advantage over *minifundios* for utilizing available technology. As a result, a relatively small percentage of the total number of farmers in Latin America have benefitted from agricultural technology, while the situation of the majority of the region's farmers remains basically unchanged.

This case study was designed to explore and evaluate a methodology which with certain modifications could be used to validate, select, and transfer agronomic technology for *minifundios*. It deals specifically with the problem of how to increase bean production on small highland coffee farms in Colombia. The basic assumption in this study is that small farmers are income seekers, aware that a larger production potential exists, but are unwilling or financially unable to risk the "stability" of their present production system for yield "maximization". The given technological level of their system therefore offers a logical option if the income seeking and risk averting polar forces are of equal strength in an environment of limited alternatives. It is when new, low risk technological alternatives are introduced and value proven through widespread demonstration trials that the equilibrium shifts toward greater productivity. The major objective of this research is to generate socially acceptable, economically viable, and biologically suitable technological alternatives for small farm bean production in the project area.

LITERATURE REVIEW

The Small Farmer: An Economic Entity

The Dual Economy Model

Rural poverty in Latin America exists within the context of an existing economic and political structure which contains two basic autonomous sectors. Jorgenson (1969) stated that the modern sector of the classical dual economy model centers on industry, urban services, and the export of production from large agricultural units. The contrasting sector consists of small farmer agriculture with a large degree of subsistence farming using traditional methods. The model views the traditional or small farm sector as a self-perpetuating force which stymies the growth impetus of the modern sector by generating insufficient internal demand for manufactured goods (Paiva, 1971; Dillon, 1975).

An inequitable distribution of income and high rates of unemployment are common characteristics of such countries. According to Healey (1972) the lowest 50% of the income earners in dual economy countries received only 15% of the total income while the top 10% received approximately half of the total income. Much of the inability of industrial expansion to absorb the urban work force is due to the capital intensive and labor saving nature of the modern industrial technology, which is being imported from the more developed countries (Thiesenhusen, 1971b; Turnham and Jaeger, 1971). Thorbecke (1971) observed that unemployment and low wages perpetuated the poverty of the poor, while high rates of return on scarce land and capital which are owned by the rich magnified their wealth.

Previous attempts to finance industrialization through the export of minerals, petroleum, and agricultural products de-emphasized traditional food production. Agricultural development strategies focused on larger, more commercial units, while condescendingly ignoring the small farm problem. Yet many authors (Owen, 1966; Mosher, 1969; Crosson, 1970; Dorner, 1971; Kanel, 1973; Streeter, 1973; Biggs and Tinnermeier, 1974; Brown, 1974; de Janvry, 1975b; Wortman, 1976) stress that economic stagnation can only be broken by increasing the agricultural productivity of small farmers. This will require a technical change in production methods or an improvement in the fixed resource base (e.g. land reform).

Small Farm Productivity

Schultz (1964) suggested that small farmers are economically motivated. They therefore need only a new profitable technology, along with the necessary input supplies and marketing channels, to break out of the static economic and cultural environment within which they operate. Other authors (Ruthenberg, 1968; Solo and Rodgers, 1972) agreed that small farmers will respond to technology as long as it is on favorable terms and they know how to use it. After a study of African peasant farming, Doyle (1974) concluded that a profitable cash crop was necessary to "break the ice" for agro-technical change in subsistence society. However, Dillon (1975) was quick to point out that productivity is directly related to the quality of the resource base, the level of the human capital in terms of education and health, and the socioeconomic ability of a farmer or farming stratum to gain access to public services. Although there is considerable variation among small farmers, in general the size (area)

and quality of their land resource is limited. Family nutrition and education levels are not commonly high, and their collective political leverage is minimal.

The political and institutional structure of less-developed countries are themselves obstacles to small farm productivity, because they determine the price and availability of technology relative to the price of goods it produces. The role of institutional incentives in determining the pace of technological change has been a popular topic in development oriented literature (Crosson, 1975; Leagans and Loomis, 1971). The social marginality of the Latin American small farmer within a malevolent political and economic environment has also been widely discussed (de Janvry, 1975a). This view has lead to the more radical proposals for improving small farm productivity (Frank, 1969; Huizer, 1972). Nevertheless the potential profitability of small farm enterprises has been shown in studies in Bolivia (Wessel, 1972), Guatemala (Johnson, 1974), Mexico (CIMMYT, 1974), Kenya (Gerhart, 1975), Brazil (Sanders and Dias de Hollanda, 1975), and Colombia (Zulberti et al., 1975).

The Small Farmer: A Social Entity

Definition of Small Farms

Although the size of land holdings is the most obvious distinction between small and larger farm units, several other characteristics have been commonly used to define "small farms". Among these are the size of the income stream generated by the farming operation (Harrison and Shwedel, 1974), the level of technology employed (Streeter, 1973; Thiesenhusen, 1971a), the organization of economic activity (Grunig,

1969), the ratio of the family labor to hired labor (Felstehausen, 1968), and the degree of integration with the national economy (Wharton, 1969). This final characteristic has been further subclassified by Adams and Shulman (1967) according to the decision-making behavior used. An "independent" *minifundio* devotes all family labor to the direct exploitation of the farm, whereas other *minifundios* are "dependent" on off-farm employment for a substantial part of the family income. These "dependent" units are usually found in clusters around main cities or large land holdings. Still other "commercial" *minifundios* are those which base production decisions on fluctuating market conditions. However perhaps the most "typical" *minifundio* in Latin America would be one using a combined or mixed production strategy in which both commercial and consumption crops are produced and family income is supplemented by off-farm employment during lulls in the seasonal farm labor pattern.

Small Farm Characteristics

Small farmers closest to the subsistence level of production provide the common stereotype of the "small farm problem". Although subsistence farmers may also be "small" in the relative or absolute sense of the word, Adams and Coward (1972) stated that it is their low level of market involvement that distinguishes them from other types of small farmers. Turk and Crowder (1967) recognized the interrelated bio-social factors which perpetuate rural poverty. For example, illiteracy encourages the persistence of primitive health concepts, poor hygiene, large closely-spaced families, and reduced purchasing power.

Grunig (1969) observed in Colombia that the extreme poverty of the subsistence level *campesinos* often leads to an attitude of fatalism in which they feel that the individual has no control over his own destiny. This attitude was not conducive to innovativeness, and was further limited by the education, nutritional status, and experience of the farm operators (Myren, 1970). While small farm agriculture typically utilizes the bulk of the available family labor and capital, and has limited access to markets and political institutions, Miracle (1968) emphasized that the major distinction between subsistence and commercial farming is the decision-making rationale.

Harrison and Shwedel (1974) concluded that subsistence level small farmers generally rely on routine traditional habit rather than on economic criteria when considering production decisions. In many peasant societies, cultural values, beliefs, and behavior patterns are as important as economic rewards and directly influence the decision-making process (Rodgers, 1969). Schultz (1964) described the reciprocal exchange principle of material gift and counter-gift along kinship lines, which is common in most peasant systems. Several authors (Spicer, 1952; Cancian, 1972; Smith, 1972) stressed the functional integration of the economic, social, and religious components of rural society. The conservative nature of peasants and their stubborn adherence to traditional norms is rooted in this social equilibrium of inter-dependent forces.

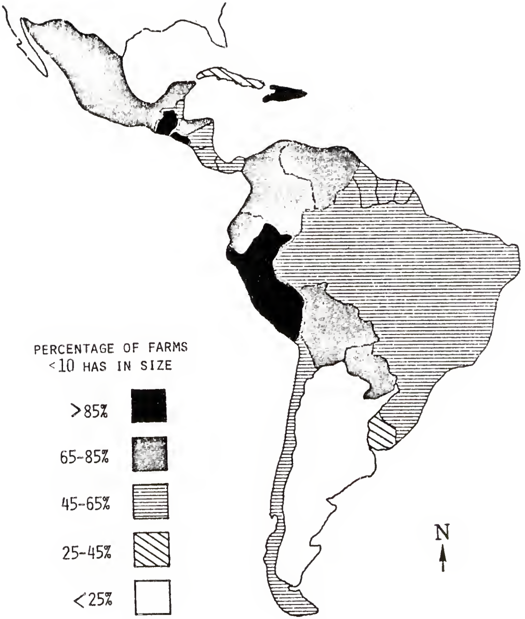
The Small Farmer: A Physical Entity

Small Farm Distribution in Latin America

The vast majority of the countries in Latin America report that over half of their farms are less than 10 hectares in size. The severity

of the small farm problem is reflected in the concentration of these units throughout the region (Figure 1). Argentina, Uruguay, and Cuba contain relatively fewer small farms than other Latin American countries, and are therefore outside this discussion. However, it should be noted that in the case of Cuba, this is primarily related to the political system of state-owned land and the plantation agrarian structure. On the extreme, small farms dominate in five countries (Guatemala, El Salvador, Haiti, Dominican Republic, and Peru) and are the serious concern of government planners in seven others (Mexico, Honduras, Venezuela, Ecuador, Bolivia, and Paraguay).

The relationship of small farm concentration to population density, racial composition, topography, and soil fertility is impossible to determine given the available statistics. Nevertheless, the heaviest concentrations of small farms are most often found in mountainous terrain and on marginal soils. There is a predominance of small farmers of Indian origin at the higher elevations where temperate climate staple food crops, such as potato, barley, and onion are produced, while small farmers along the tropical continental coast are usually of African origin. The *mestizo* small farm population at intermediate elevations is associated with a wide variety of staple food crops (plantain, maize, bean, etc.) as well as cash crops (coffee). In the Caribbean and some Central American countries (e.g. El Salvador), the concentration of small farms is directly related to the rural population density per arable land area (Maeda et al., 1970). However this Man/Land Ratio is inapplicable to those South American countries which have a large, as yet unexploited , segment of their territory in the tropical Amazon basin. According to



Source: Econ. Com. for Latin America. 1972. *Estudio Economico de America Latina*. United Nations, Rome, Italy.

Organizacion de los Estados Americanos. 1974. *America en Cifras. Situacion Demografica. Instituto Interamericano de Estadistica*. Washington, D.C.

Figure 1. The distribution of small farms in Latin America.

FAO statistics, 40% of the total arable land area of Latin America is owned by only 2% of the population (the *latifundistas*), while 25% of the agricultural population are subsistence farmers (with less than five hectares) and 41% are landless peasants (U.N., 1968).

The Colombian Small Farmer

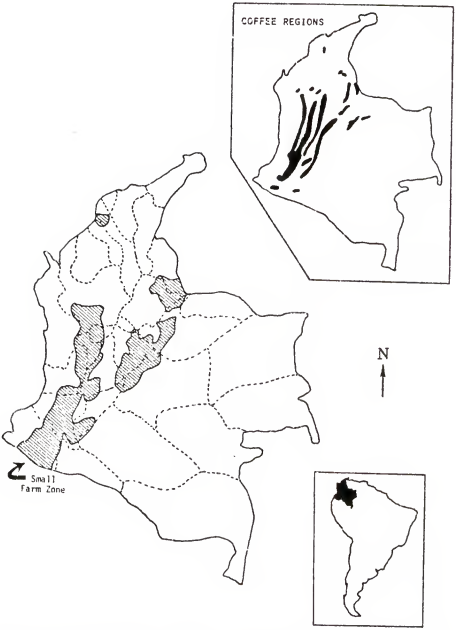
In Colombia, where 72% of the farms are less than 10 hectares (Table 1), the location of small farms is more closely related to topography than to departmental political boundaries (Figure 2). In a very comprehensive review of the subject, Posada (1974) noted that in the highland Andean region of the country which contains 76% of the economically active population, 86% of the farms are less than 10 hectares. Although small farmers occupy only 7% of the cultivated land area, they account for over one-half of the total value of agricultural production which has fueled the argument that the potential for meeting the food production demands of the future lies in efficient, intensively managed units rather than large exploitations.

A strong technical assistance program has been extended to small farms located in the coffee producing region along the slopes of the three major Andean ranges of Colombia, because of the importance of this crop to the national economy. Dambe and Thorbeck (1974) pointed out that those small farms situated in areas climatically unsuited for coffee production have been relatively unaffected by technological advances. The poverty associated with subsistence level small farms is more obvious in these areas.

Table 1. Distribution of arable land by size of holding (Colombia).

Farm Size	Number		Area	
	1960	1970	1960	1970
has	%			
<10	76.5	73.1	8.8	7.2
10-50	16.6	18.5	15.4	15.0
50-200	5.2	6.3	20.8	21.8
200-2500	1.6	8.3	38.5	36.5
<2500	0.1	0.1	20.2	19.5

Source: *Organizacion de Estados Americanos.* 1974. *America en Cifras: Situacion demografica. Instituto Interamericano de Estadistica.* Washington, D.C.



Source: *Banco de la Republica.* 1964. *Atlas Economico de Colombia.* Bogota, Colombia

Figure 2. The concentration of small farms in Colombia.

A study of the nutritional status of one such region (Swanberg and Shipley, 1975) revealed a dietary deficiency of all nutrients except iron, vitamin C, and thiamin. Vitamin A and B deficiencies were most apparent along with protein-calorie malnutrition in the infant population. Nevertheless, their study showed a better than average daily diet for pre-school children, which infers that rural families are especially concerned with the nutritional well-being of their children. Other studies of Colombian small farm agriculture (Haney, 1972; Whittenbarger and Havens, 1973; Spijkers and Morales, 1974; Tobon, 1974) confirmed the relationship between staple food crop production and family income.

The Small Farmer in the Development Context

The Role of Small Farmers in Colombian Economic Development

The small farm problem encompasses not only the physical distribution of land holdings by size, but also the distribution of income and social power in the overall process of economic development (Wessel,1972). In Colombia, 15% of the agricultural population earns some 65% of the annual agricultural income (Berry, 1971). This income disequilibrium would be even more significant if Colombian small farmers did not account for approximately one-half of the nation's coffee production, which represented 31.7% of the total value of crops in 1970 (Weil, 1970). Since not all Colombian small farms produce coffee, there is a range of small farm incomes. Nevertheless, Posada (1974) reported that this range is only 21-60% of the average national income. Low farm incomes stifle the purchase of industrial products. However, it is impossible for this low income

sector of the population to become better purchasers until they become better producers, thereby multiplying their purchasing power.

Colombia is typical of the Latin American countries whose economy is based in large part on agriculture, which employs almost half of the economically active population. Aside from the relatively obvious need to expand food production to meet the needs of a growing population, Feder (1971) emphasized the need to improve the standard of living in the rural sector. Table 2 indicates that more than half of the Colombian agrarian population lives on farms less than five hectares in size. Berry (1971) noted that 20% of the agricultural population was unemployed and agricultural underemployment estimates run as high as 55%. At the same time, rural illiteracy rates (41% in 1964) are double those of the urban population (Atkinson, 1969). High rural unemployment and underemployment, coupled with disproportionate salaries and living standards between small and large farmers push people off the farms, while educational opportunities and other urban attractions pull people into cities. Colombian urban centers are growing at an annual rate of 5-7% and will double their current population in 12-15 years (U.N., 1968). Many of the urban social ills experienced today, and much of the ferment for radical political change in Colombia can be traced to social and economic inequality and the inability to maintain the economic productivity of the rural population.

Obstacles in the Transfer of Technology to Small Farmers

There are several reasons why small farmers have been unable or unwilling to adopt available agricultural technology. Although there

Table 2. The distribution of farms by size in Colombia (1963).

Department	Farm size (has)			
	<5	5-20	20-100	>100
	%			
Antioquia	60.7	20.5	12.3	6.5
Atlantico	48.5	14.6	17.8	19.1
Bolivar	56.4	17.7	16.1	9.8
Boyaca	66.5	22.8	7.4	3.3
Caldas	50.2	30.5	13.5	5.8
Cauca	54.7	31.3	11.0	3.0
Cordoba	50.9	16.7	20.3	12.1
Cundinamarca	60.2	26.3	9.8	3.7
Huila	37.0	30.3	24.0	8.7
Magdalena	47.4	12.7	19.2	20.6
Neta	30.8	22.4	25.8	21.0
Narino	60.1	30.2	8.3	1.4
Norte Santander	31.8	41.0	22.1	5.1
Santander	45.5	33.8	15.2	5.5
Tolima	43.3	31.1	18.2	7.4
Valle Del Cauca	40.8	31.6	17.0	10.6
Mean	53.3	26.1	13.8	6.8

Source: *Banco de la Republica*. 1964. *Atlas Economico de Colombia.* Bogota, Colombia.

is a tremendous variation in the resource endowment, productive opportunities, skills, and socioeconomic status of small farmers within and between countries, small farmers have many physical, economic, and technical constraints in common (Bunting, 1976). In addition to the limited quality and quantity of their land base, small farmers typically have insufficient capital on hand to purchase necessary soil amendments, pesticides, or new plant varieties and breeds of animals, with which to improve their physical production base (Thiesenhusen, 1971a; Dillon, 1975).

Many remote small farms have limited access to credit and technical assistance institutions, and where credit does exist, it is usually crop specific and expensive due to high interest rates (Bottrall, 1976). The lack of official land titles and the farm size itself often prevent small farmers from qualifying for institutional credit. The sheer numbers and geographical dispersion of small farmers make the supervision of credit difficult. The amount of credit, which is available from institutions, is often inadequate to cover the cost of new technology. Some credit can be obtained from local stores and wholesale merchants, but interest rates calculated on a monthly basis are exceptionally high from these sources.

New technology often implies the use of new inputs. The cost of these inputs relative to crop prices and their unavailability discourage the adoption of new technology. Gilpatrick (1972) reviewed the crucial marketing obstacles facing small farmers. The introduction of new technology often results in a surplus of perishable commodities, which glut inadequate marketing facilities. As a result, commodity prices fall

rapidly which reduces the profit incentive of the new technology. Since each individual farmer produces a relatively small amount of any given crop, they often feel impotent and powerless at the marketplace. Cooperatives and commodity associations provide credit, assure input supplies, and improve the collective bargaining position of small farmers, augmenting their economic and political power (Maeda et al., 1970).

Heibert (1974) pointed out that small farmers generally have very little access to commodity and input price forecasts. Without this information, farm management decisions for cash crops must be made blindly based on conservatism, tradition, and experience from previous seasons. Storage losses prompt many small farmers to sell most of their produce at harvest, when prices are at their lowest. Mellor (1969) stated that it is this combined insecurity of not being able to obtain the necessary credit, inputs, or favorable product prices that deny small farmers the incentive for adopting new and expensive technology.

Finally there is the obstacle of risk. Technological innovations in one region seldom attain the same level of success in another region (Mellor, 1973; Pastore, 1974). This inability to transfer regional successes make low income farmers skeptical of even the most convincing promotional campaign, because it is they who will have to assume the financial responsibility should the new technology fail to perform as promised under their local environmental conditions and commodity price fluctuations. Cancian (1972) analyzed the decision-making process with a stratification of farmer wealth. He confirmed that the willingness to take risks is directly dependent on the farmer's socioeconomic status.

Wealthier, more commercial, farmers can afford insurance and economic diversification, so that the impact of a crop failure is not as devastating on their capital reserves.

Mellor (1969) evaluated the sources of uncertainty in the modernization of traditional agriculture. These sources were technical (new technology may not work locally), related to price instability (reliable price forecasts were unavailable), and based on climatic variation (rainfall fluctuations). Tinnermeier (1974) added the variability of inputs and services to this list. Small farm agricultural systems are structured to maximize yield stability within a sphere of uncertainty created by these exogenous factors. Whereas small farmers attempt to minimize risk by diversifying the crops that they produce by concentrating on self-sufficiency and family labor and by planting several varieties of the same crop, new technology is usually monoculture cash crop oriented with only one variety of one crop in any given field. This new technology was generated under experimental conditions which were optimum for agriculture. The likelihood that this new technology had been thoroughly studied under conditions resembling those of the small farm production environment for several seasons is slim, and would not overcome the skepticism of practical-minded small farmers.

Case Studies in the Transfer of Technology to Small Farms

Even though many small farm development projects have been initiated around the world, very little information appears in the literature. The current shift in attention toward small farmers, in response to criticism of the Green Revolution (Falcon, 1970; Bieri et al., 1972;

Wade, 1974), will undoubtedly bring an upsurge of small farmer related literature in the next decade. Adams and Coward (1972) provided the most thorough synthesis of the available information to date. Their study isolated two distinct types of development projects aimed directly at small farmers and a third more passive type, in which it is hoped that the small farmer situation will improve in response to a healthy overall agricultural development program. Since this latter approach emphasizes commercial production, with small farmers imitating commercial farm techniques and successes according to the "trickle down" model of technology diffusion (Leagans and Loomis, 1971; Owen and Shaw, 1972), it is only mentioned in passing.

The Puebla Project in Mexico provides the most outstanding example of the integrated development approach in Latin America. The philosophy of this approach is related to the complexity of the small farm problem itself and the proven fact that there is no simple solution. Technological innovations for maize production, improved credit, marketing and transport facilities, more effective extension, and economic incentives are the major ingredients in this strategy (CIMMYT, 1974). The Puebla Project was designed to create a socioeconomic environment conducive to small farm productivity. The social impact of this package of production services was to be measured in terms of the number of farm families involved, while the economic impact was indicated in the amount of credit provided per year and the total value of the maize produced in the project region (Sanchez, 1970). Also some emphasis was placed on training technicians to work in other small farm development projects, which would follow the model of the Puebla Project. Perhaps the greatest

distinction of the Puebla Project has been the success with which it has been able to integrate research and extension activities with government infrastructure services. The obvious limitations of this integrated approach are related to the time and cost involved. The Puebla Project is now in its tenth year, during which time several million dollars have been invested annually. For many countries the Puebla Project Model is too expensive and slow, and is not politically expedient. Nevertheless, the project did succeed with one crop in one homogenous small farmer zone and the longevity of the effect will far exceed other short-term, low budget efforts.

Colombia's "Integrated Rural Development Projects", which were initiated in 1972 by the *Instituto Colombiano Agropecuario* (ICA), are an application of the integrated development approach on a national scale. The extension service, which preceded the establishment of these projects, had identified the lack of community organization, education, credit, and complementary inputs as the major reasons for unsatisfactory rates of adoption of new technology (Rochin and Londono, 1975). As a result, social welfare (employment, health, and education) was emphasized in these inter-institutional, multi-objective projects along with agricultural development. Project zones were selected on the basis of the potential farm profits, which would result from access to technology, inputs, and marketing facilities. In general, farms in these zones ranged in size from five to 50 hectares, which include both small farms and commercial scale units. A multidisciplinary team of agronomists, veterinarians, and home economists was assigned to each zone to provide technical assistance and supervise *Caja Agraria* credit.

There are presently 22 Integrated Rural Development Projects throughout the country.

Two noteworthy features of one of these projects (the Caqueza Project near Bogota) deserve special mention. The first deals with a risk-reducing credit scheme, whereby farmers are provided with an incentive for adapting a "complete package" of agricultural practices and then given credit terms which almost guarantee profit (Zulberti et al., 1975). The major criterion for obtaining the low interest credit is the acceptance of the "complete technological package", rather than providing credit for a certain commodity and giving farmers a free choice of inputs. Since research on the complete package has revealed a high probability of obtaining acceptable yields, risk is reduced by this procedure. The terms of the contract also specify that the farmers keep all that they produce up to an amount equal to the cost of the production. If production was not sufficient to recover production costs, the farmer would not have to pay for the purchased inputs. However, if production exceeded this break-even point, the excess was divided equally between the farmer and the lending agency.

The second point concerns the adoption of improved technology. Zulberti, Swanberg, and Zandstra (1975) reported dramatic increases in both yield (202% for maize and 51% for potato) and net returns (253% for maize and 30% for potato) resulting from incorporation of improved production technology in the zone. This new technology consisted basically of using new varieties, optimum population density, and insect control. The improved maize technology included an additional fertilizer recommendation. In spite of these impressive agronomic and economic

gains a subsequent survey of farmers receiving supervised credit revealed that recommended varieties, population densities, and insect control were widely adopted for maize production but not for potato production. In contrast the adoption rates for fertilizer in potato production were double those for fertilizer in maize production. Farmers were more receptive of credit for potato production in spite of very unstable potato prices, and the demand soon outran the supply. Much less enthusiasm was shown for credit to purchase the improved technology inputs for maize, even though maize had a longer history of research and extension and the potential returns were greater with this crop. This implies that production data alone are not the main criteria used by farmers to evaluate alternative technologies. This differential response was apparently due to the fact that the recommended maize technology represented a substantial change in the normal production system, particularly in respect to the costs involved, while that of the already technified potato production required minimal changes. The farmers who attended field days, but did not solicit credit for maize production also were studied. It was discovered that they selected and adopted only some of the recommendations and used sub-optimal input levels. The performance of the improved variety in the absence of supplementary inputs was unsatisfactory and the farmers who adopted only the varietal component soon returned to using local varieties. Similar results had been observed in the Puebla Project in Mexico (CIMMYT, 1974), and in other regions of Colombia (Tobon et al., 1975).

The economic analysis of the traditional and improved production systems for these two crops showed a 575% increase in variable (cash)

costs for improved technology in maize compared to a 10% increase in the variable costs with potato. Farmers were apparently unwilling to accept such an increase in production costs, partially because it forced them to receive credit. Tobon (1975) suggested that such behavior is based on the desire to avoid risk. A farmer with sufficient capital experiences less risk than one on credit, because in the event of crop failure he loses only his financial investment whereas the farmer on credit loses interest, family security, and perhaps land collateral. A socioeconomic survey in the Caqueza project area (Shipley and Swanberg, 1974) discovered that the average annual family income in the region was US$ 222, of which 94% was spent for food. The remaining capital on hand was not sufficient to purchase the new technology and the scale of the total investment was well outside the realm of family economics. In contrast, the new potato technology would logically appear more reasonable to low income farmers, because it required only modest changes in production costs and labor demands. This emphasizes the importance of understanding the many interrelated factors which influence the decision-making process of small farmers. Too often low adoption rates are blamed on the stubborn, irrational, peasant nature of small farmers or on the bureaucratic incompetency of the extension service rather than on those who design and create the new technology.

The Comilla Project in Bangladesh and the Intensive Agricultural Development District Programs in India (Malone and Johnson, 1971) are good examples of the integrated approach outside of Latin America. Both of these projects pre-date the Latin American examples by almost 10 years. The Comilla Project focused on building local organizations

(cooperatives, training centers, local irrigation programs, etc.) which could tie farmers into wider service organizations. Relatively little attention was given to generating new profitable technology. Instead efforts were directed at testing available technology (new crop varieties, irrigation pumps, tractors, sprayers, etc.). A considerable quantity of "community development" village level literature emerged from these activities, and the social attitudes of many small communities were oriented toward problem-solving.

The Indian District Programs emphasized agricultural development more than building service organizations. The introduction of IRRI (International Rice Research Institute) rice varieties and CIMMYT (*Centro Internacional de Mejoramiento de Maiz y Trigo*) wheat varieties in the mid-1960's was critical to the success of many of these programs. It should be noted that with very few exceptions (Andersen, 1971) the small farm literature reports successes. Governments and financial organizations are apparently less willing (or politically able) to report failures, thus depriving future planners of valuable guidelines and forcing many technology transfer projects into errors that perhaps could have been avoided.

Examples of the non-integrated approach to small farm development are much more widespread than those of the integrated approach. A great diversity of projects can be classified under the "non-integrated" heading and these are represented to various degrees in most Latin American countries. These include credit for small farmers, land reform, the formation of cooperatives, and general community development. The Peruvian Supervised Credit Program (Adams and Coward, 1972), the Colombian Community Action Programs (Edel, 1969), and the Foundation for the

Promotion of Cooperatives (FPC) in El Salvador (Maeda et al., 1970) are case studies in specialized aspects of this approach.

Technological Packages in the Transfer of Technology

Projects aimed at designing technological innovations for small farms can also be numbered among the non-integrated small farm development strategies. The earliest references to the formulation and testing of "technological packages" for small farmers deal with rice production in Asia (Cummings and Cline, 1971; Turk, 1971; IRRI, 1972). India began testing rice technological packages in 1966 in an attempt to screen varieties and demonstrate the advantages of the IRRI (International Rice Research Institute) high-yielding varieties in farmer's fields (Hall, 1973). At the same time, valuable economic data were obtained on the farmer's traditional production system, allowing researchers to design complementary inputs within the scope of the small farmer's land, labor, and capital resources. These modifications and refinements of technology specifically for small farm production resulted in rapid and widespread adoption. Wittwer (1975) reported a 50% adoption rate for high-yielding rice varieties in the Philippines within a six-year period.

Rice "microkits" were tried in other Asian areas (Feuer and Obordo, 1972) to maximize the dispersal of technology to small farmers. These microkits contained five varieties of rice, which were to be planted in the farmer's rice field alongside his local variety. Enough seed was included to seed a total of 50 m^2. Two levels of fertilizer and two levels of insecticide were also included in the package. It was

calculated that seed yields of the best variety would be sufficient to plant one-fourth hectare the following season. In this way, small farmers themselves multiplied seed of the best varieties, which they had selected, thus eliminating the necessity of purchasing government-supplied seed.

A similar project was initiated in Nigeria (Africa) by IITA (International Institute of Tropical Agriculture) with both rice and maize as part of the National Accelerated Food Production Program (Suler, 1976). These minikits included four improved varieties and one local variety, two fertilizer levels, and a record book. One farmer in each village was selected by local extension agents and village leaders to receive and manage the microkit experiment. IITA researchers visited many of these farmers and modified research according to the field problems that they had observed. In 1975, 425 rice kits and 560 maize kits were distributed throughout 19 Nigerian states. Preliminary results indicate that small farmer adoption rates are enhanced by these on-farm demonstrations of productivity and profitability.

In Latin America, IICA (*Instituto Interamericano de Ciencias Agricolas*) in Costa Rica and CIAT (*Centro Internacional de Agricultura Tropical*) have pioneered multiple cropping research aimed at understanding and improving small farm production systems. Both CIMMYT and CIAT have also been involved in on-farm validation of maize, wheat, bean, and yuca technology in Mexico and Colombia. ICTA (*Instituto de Ciencia y Tecnologia Agricola*) is using a multidisciplinary methodology to identify small farm problems, design a package of appropriate technology, and test the technology at the farm level in Guatemala (Hildebrand, 1976).

The prerequisite is that the technology be directly and immediately applicable without needing to depend on a non-existent infrastructure or the development of new markets. In this way, farmers begin benefitting from the research program while varietal refinements and fertilizer response studies continue. This approach also allows the farmers to manage the farm level evaluations themselves and to screen out inappropriate technology. Each farmer participant is required to pay all expenses except for technical assistance and to provide all labor. If very few farmers volunteer, the technology is obviously too difficult or too risky. In 1975 and 1976, farmer-managed trials were established on a total of 127 farms to determine the practical value of experimentally generated technology (ICTA, 1976).

The design and packaging of technological innovations for small farmers are one component of a "people-oriented development strategy" (Brown, 1974; Schumacher, 1975). This "self-help" or "technology for the masses" evolved from the failure of previous development strategies to improve the nutrition and incomes of the rural poor. The international "material transfer" of high yielding cereal varieties, which was responsible for the Green Revolution, represents only the first of three stages in the international diffusion of technology as described by Janick et al. (1974). As the short term successes of the Green Revolution fade into popularized pessimism, there is a tendency to overlook the second ("design transfer") stage of technological diffusion. Technological packages are central to the design and adaption of technology for specific targets, such as the rural poor.

Guidelines for the Transfer of Technology

Although it may not be possible to rekindle the early glory of the Green Revolution, the stage is now set for accelerated "design transfer". The need to invest resources in agriculture and specifically in the traditional small farm subsector has been recognized. The myths concerning the general transferability of technology (from temperate developed countries to less developed tropical countries) and the unresponsive nature of small farmers have been dispelled. International financial institutions capable of funding development now exist, and pioneering case studies in the transfer of technology provide a sufficient technological base.

Brown et al. (1975) discussed the research framework that is necessary to facilitate the long-term transfer of technology to small farmers. The responsibility for crop and area specific "strategic" research rests with the international institutes. National institutes must conduct "tactical" research toward the identification of technological innovations and support services to overcome regional problems. Validating and selecting appropriate technology at the farm level implies "operational" research, which is the task of teams of locally based scientists with national coordination. Underlying this framework is the basic and supportive research being done by universities in the developed countries.

Spicer (1952) produced one of the classical references on understanding the social and cultural dynamics involved in the adoption of new technology. He concluded that people do not vary their customary behavior unless they feel some need which existing ways do not satisfy.

Given sufficient incentive, they will invent or borrow from some other people a technique or form of organization to satisfy that need. Often, the resistance to government sponsored innovations is not centered on the specific project itself, but on the way in which it is administered. People's energies become channeled into opposition to the innovator, while the innovation itself becomes a symbol of that opposition. Since people respond collectively as members of formal (kinship) and informal (cliques) social groups, the introduction of innovations must be sensitive to the fabric of human culture.

In a thorough review of the theoretical and empirical aspects of the diffusion of innovations, Rodgers and Shoemaker (1971) also stressed cultural fit and client participation. Heibert (1974) emphasized that it is the nature of the information used to promote new ideas and not the quantity of information made available that determines adoption rates. Illiterate and uneducated farmers must be able to decode and understand the information if communication is to succeed. In a study of Colombian peasant farmers, Deutschmann and Fals Borda (1962) reported that the adoption pattern for several innovations (chemical fertilizer, a livestock feed concentrate, a fungicide, a potato variety, a chicken vaccine, and a manual sprayer) followed an S-shaped "curve of innovation". A very slow rate of acceptance at the start of diffusion was followed by a sharp linear increase in adoption, which tapered off again as the last members of the group adopted the change over a more extended period. The more "outward oriented" individuals were the first to receive impersonal information from outside the community and adopt the new practices, while on the other end of the curve, the laggards waited until their neighbors succeeded.

Technology and Farm Size

Some controversy still exists in the literature concerning the relationship between adoption and farm size. Although the Green Revolution technologies are basically biological and chemical rather than mechanical in nature, and therefore do not give rise to such an economy of scale as to place small farmers in a disadvantageous position compared to larger farmers (Turk, 1971), several authors (Fonseca, 1966; Falcon, 1970; Bieri et al., 1972; Schluter and Mellor, 1972; Esmay and Faidley, 1973; Gerhart, 1975) report much more rapid adoption by larger farmers. Since larger farmers are better able to take risks and purchase expensive complementary inputs, they have been the first to realize profits from the expanded per hectare production.

Dasmann et al. (1973) cited an example in India, where a major innovation substantially altered the supply situation, depressing market prices to a point where larger farmers with lower production costs dominated the market. Small farmers, who were slower to adopt the technology, experienced much lower profit margins. In this case, the new technology benefitted larger farmers sooner and to a greater extent, thereby widening income disparities in the region. However, Hopper (1976) argued that the success of high yielding wheat and rice varieties in the Green Revolution is proof that small farmers do benefit from technological innovations where the infrastructure is adequate. Other authors (Rask, 1964; Moock, 1973; Hodgdon, 1974; Terman and Hart, 1977) provide evidence to support this thesis, adding that in some cases economies of scale are offset by more intensive input use on small farms.

To enhance small farm adoption of new innovations a distinction must be made between "labor saving" and "land saving" technology as defined by Hayami and Ruttan (1971). Labor saving mechanical innovations have been economically successful where labor is scarce and expensive. However, in small farm agricultural systems, land is the common limiting factor. Therefore, efforts to improve small farm productivity must focus on innovations which will increase yields per unit land area, rather than yields per farmer. A survey of 32 Philippine villages (IRRI, 1974) revealed significantly higher rates of adoption for high yielding rice varieties than for herbicides, tractors, and mechanical threshing equipment, confirming small farmer preference for land saving technology. Brown et al. (1975) noted that large scale, mechanized farming is less productive per unit area than the labor intensive agriculture practiced by small farmers. However, data from Colombia (USDA, 1970) suggested higher yields on larger farms for banana, rice, coffee, potato, and wheat, because large commercial farmers utilize improved technology, while small farmers do not. It is interesting that for the period 1948-1968 some crops such as maize and bean did not show a yield by farm size interaction, indicating the absence of improved technology for these crops.

Small Farm Production: The Technical Context

Bean Production

As is common with agricultural statistics in Latin America, there is some disagreement in the literature concerning total bean production in Colombia. For example, data from the *Ministerio de Agricultura*

(1974) reported a production of 41,900 tons of beans in 1969 with an average yield of 630 kg/ha, while DANE (1972) estimated 48,000 tons and 700 kg/ha, respectively, for the same year. CIAT (1973) stated that Colombia's percentage contribution to Latin American bean production slipped from 2.5% in the early 1950's to 1.1% in the late 1960's. Sanders and Alvarez (1977) calculated an average annual per capita bean consumption in Colombia of 5.7 kilos for the period 1972 to 1974, which is approximately one-fourth that of the major Latin American producers, Mexico and Brazil. Flores and Elias (1973) found that there were no differences in bean consumption between rural and urban areas or between socioeconomic groups in Central America, suggesting that beans are one of the most important items in the Latin American food pattern. Beans account for approximately 20% of the protein intake of Central American families.

The available statistics for Colombia suggest an average annual production increase of 4% compared to a 2% average annual increase in yields. It therefore appears that production is keeping pace with the 3.4% population growth rate (Ruddle and Barrows, 1974) and a stable consumption pattern by an expansion of bean acreage. In this respect, Colombia is symbolic of most Latin American countries. Average bean yields for the region ranged from 580 kg/ha to 620 kg/ha for the 20 years prior to 1971, while the average bean yield in the United States was 1,360 kg/ha (CIAT, 1975a). Under experimental conditions, maximum yields of 4,260 kg/ha for bush bean and 5,500 kg/ha for climbing bean have been obtained (CIAT, 1975b).

Posada (1974) reported that small farmers account for 56% of the Colombian bean production. A survey of the four major bean production departments in Colombia revealed a yield of 1,118 kg/ha on large farms compared to a yield of 683 kg/ha on small farms (CIAT, 1975b). This yield difference was attributed to the use of irrigation, improved varieties, insecticides, and fungicides. Credit and technical assistance were identified as critical factors in determining bean yield. In the two primary small farm departments (Antioquia and Narino) where the average farm size is four hectares, only one-half of the farmers received credit and only one-third of the farmers had access to technical assistance. Over 95% of the beans produced in these departments were grown in association with other crops. In spite of the fact that Colombian bean prices have been four times greater than maize prices for the past 25 years (Francis and Sanders, 1978), the most common associate crop was maize.

Londono and Anderson (1975) surveyed 372 small farmers in three departments of Colombia. They identified low planting densities, ecological factors (rainfall fluctuations, low soil fertility, and pests), and the high cost and general unavailability of technical inputs as the main yield constraints for small farm corn production. Heavy crop losses at early vegetative stages were common and reseeding was frequently necessary due to insect damage or inadequate rainfall. Tobon (1974) noted similar problems with small farm bean production in the department of Antioquia, adding that poor seed quality was also a factor.

Intercropping

In recent years, a considerable quantity of literature on intercropping and other multiple cropping systems has begun to appear (Dalrymple, 1971; Papendick et al., 1977). The popularity of legume and cereal intercropping has been widely reported. In Latin America, intercrops of bean (*Phaseolus vulgaris* L.) and maize (*Zea mays*) constitute the most common legume-cereal association. Bean-maize intercropping is particularly prevalent on small farms. Therefore, the improvement of small farm productivity depends to a large extent on an understanding of interspecific competition. Such information also serves to complement the huge volume of existing literature dealing with crop monocultures, such as bean monocultures (CIAT, 1976a).

Most of the intercropping information is of a promotional nature. Narang et al. (1969) stated that intercropping diversifies production, reduces pest problems, and increases the efficiency of fertilizers and irrigation. A continuous vegetative cover protects the soil surface from excessive heat and heavy rains, conserving both soil moisture and soil fertility. Mixed farming obviously supplies small farmers, particularly those at subsistence level, with a range of foodstuffs for a better balanced diet, and at the same time, reduces the risk and storage problems of monoculture farming (Francis et al., 1977a). Norman (1970) reported that the gross returns from intercropping more than compensate for the additional labor costs involved. Harwood et al. (1973) found that light interception with intercrops was 40-50% higher than that of monocultures, and Bantilan et al. (1974) stressed the importance of crop leaf area index in controlling weeds. Williams and Joseph (1970)

discussed the pattern of crop canopy development in intercropping systems. Okigbo (1976) pointed out that the roots of different species absorb nutrients at different depths and at different times. Francis and Heichel (1973) compared the cultural energy (labor, chemicals, fuel, etc.) inputs with the caloric output of cropping systems. They emphasized that intercropping is more efficient in the utilization of land and cultural energy than are monocultures of the crop components.

Interspecific competition for light, nitrogen, and water is the dominant theme of intercropping systems (Kurtz et al., 1952). Hart (1974) ecologically classified the interspecific relationships of polycultures into four groups (commensalistic, amensalistic, monopolistic, and inhibitory) according to the effect of the association on the member species. Aguirre and Miranda (1973) described four bean cropping systems in El Salvador, and Alvarez (1976) reviewed bean associations in the Huila department of Colombia. Other authors (Moomaw and Hedley, 1971; Ruthenberg, 1971) discussed the salient features of cropping systems throughout the tropics.

There is considerable evidence in the literature that the total productivity of intercropping is greater than that of monocultures for the individual species involved (Evans, 1960; Evans and Sreedharan, 1962; Enyi, 1973; Harwood et al., 1973; Baker, 1974; Pinchanat, 1974; Soria et al., 1975; Francis et al., 1976b). In some cases the corn component of the intercrop appears to benefit from the presence of the legume (Alexander and Genter, 1962; Pendleton et al., 1963). Alvim (1969) explained this by the fact that the decrease in the assimilation rate of beans due to the shading of maize was offset by the increase in maize

assimilation as a result of reduced self-shading in the mixed stands. In other cases the legume yield of the intercrop was depressed, while the maize yield was not affected (Agboola and Feyemi, 1971; Herrera and Harwood, 1973; Dalal, 1974). Francis et al. (1976a) reported reduced maize lodging and *Spodoptera frugiperda* problems and a higher land use efficiency when climbing beans were associated with maize. Their studies over several years discovered a genotype by system interaction with maize, in which the ranking of maize varieties in order of productivity in association with bean was different than in monoculture. This indicates that farmers select maize varieties with specific characteristics for each planting system. However, no genotype by system interaction was found with beans.

Bean Yield Determinants

Loomis and Williams (1963) stated that in the presence of sufficient nutrients, water, and pest control, the maximum productivity of a crop plant depends on the rate of light interception and carbon dioxide assimilation. Austin and Maclean (1972) found that photosynthesis rates and total plant growth in beans are temperature dependent. Appadural and Rajakaruna (1967) noted that the photosynthesis of the bean pods account for 10% of the bean yield. Varietal differences in carbon dioxide uptake and photosynthetic efficiency were found to be quantitatively inherited with a relatively few genes involved and some dominance for low photosynthetic efficiency (Izhar and Wallace, 1967).

Flowering is influenced by the interaction of temperature and photoperiod. Coyne (1966) observed that some varieties were photoperiod sensitive under diurnal changes in temperature and not under constant

temperature. High temperatures, especially during flowering, reduced the total number of flowers, the number of flowers that set seed, the weight of the pods, and the number of beans per pod (Mack and Singh, 1969; Smith and Pryor, 1962). Moisture stress at flowering decreased the total weight of green pods 71% compared to a 53% reduction at the pre-flowering stage and a 35% reduction at the post-flowering stage (Dubetz and Mahalle, 1969). Stobbe et al. (1966) discovered that the yield components directly affected by moisture stress at flowering were the number of pods per plant and the number of beans per pod. Drought tolerance in certain bean varieties was related to their ability to maintain photosynthesis under high water stress and to provide substrates to maintain normal respiration rates (Coyne and Serrano, 1963).

Wallace and Munger (1966) studied the physiological basis of yield differences in six bean varieties. They concluded that there is a close relationship between plant growth rates and leaf area index. However there was a lower net assimilation rate at the very high leaf area indexes due to mutual leaf shading within the canopy. Crookston et al. (1975) noted a 38% reduction in photosynthesis per unit leaf area as a result of shading. Defoliation at flower initiation decreased yields 29%, while defoliation during pod filling resulted in a 40% yield reduction (Quinones, 1965; CIAT, 1973). Bean yields were shown to be positively correlated with the number of pods per plant and the number of beans per pod, but a negative correlation exists between these variables and seed size (CIAT, 1974). In general, climbing bean varieties have 30% more pods per plant and 45% more beans per pod than bush bean varieties (CIAT, 1975a). However varieties in the intermediate Type III classification also have a high yield potential.

Optimum bean population densities of 25 plants/m^2 for bush bean and 12 plants/m^2 for climbing bean have been established (Bastidas and Camacho, 1969; CIAT, 1974). Other authors (Appadural et al., 1967; Adams and Schulman, 1967; Willey and Osiru, 1972; Edge et al., 1975; Bennett et al., 1977) have observed that the number of pods per plant is the most sensitive yield component of beans. This yield component was the first to be affected by increasing population densities. Crothers and Westermann (1976) noted that plant maturity was advanced 7-10 days at higher densities.

Bean yields are also influenced by soil fertility. Phosphorus deficiencies have been shown to be the major limiting factor for bean production in Brazil (Guazzeli, 1973), Costa Rica (Martini and Pinchinat, 1967), Puerto Rico (Abruna, 1974), and Colombia (CIAT, 1974). Howeler and Leon (1977) noted that bean production was more limited than maize production by low phosphorus levels. Their experiments showed a significant bean yield response to band applications of triple superphosphate with levels as high as 300 kg P_2O_5/ha.

Of the 208 insect species that attack beans in Latin America (CIAT, 1972), a farm level survey in Colombia (Londono, 1977) encountered damage due to leafhoppers (*Empoasca kraemeri*), leaf miner (*Liriomyza* sp.), thrips (*Sericothrips* sp.), and aphids, most frequently. Angular leaf spot (*Isariopsis griseola*), bacterial blight (*Xanthomonas phaseoli*), and rust (*Uromyces phaseoli*) diseases were identified as the major diseases which most effected bean yields; however anthracnosis (*Colletrotrichum lindemuthianum*) was occasionally very destructive. Many of the bean diseases were found to be seed transmitted. From data obtained in this survey, the author concluded that disease-free seed and the application of appropriate fungicides could increase small farm bean yields 21%.

METHODS AND MATERIALS

Site Description

Selection Criteria

The selection of a small farm region within which to study the validation and transfer of bean production technology was conditioned by the nature of the study itself. Farm level research required institutional collaboration between a local experiment station and a national technical assistance service. In this case, the *Centro Internacional de Agricultura Tropical* (CIAT) served as the source of the agronomic bean technology which was to be applied. This fact confined the choice of technical assistance agencies to those within a reasonable radius of the main CIAT experimental station near Palmira, Colombia. Two possible candidates were the *Instituto Colombiano Agropecuario* (ICA), which was working in an integrated rural development project near Santander de Quilichao in the southern Cauca Valley, and the *Federacion Nacional de Cafeteros de Colombia* (Coffee Federation) whose work spanned the entire *Cordillera Central* and much of the *Cordillera Occidental* in the Valle department.

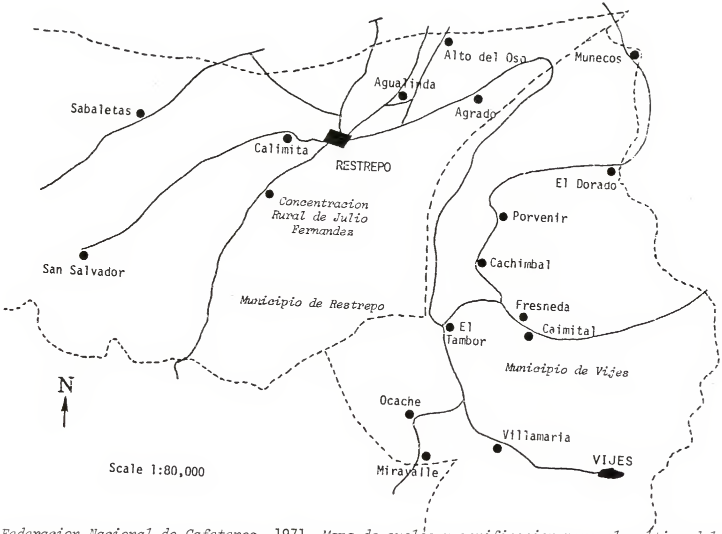
After visiting both regions and meeting the local extension personnel, the decision was made to coordinate this research with the on-going extension activities of the Coffee Federation. This decision was influenced by the quality and organization of the extension personnel and the production environment to their clients. Since coffee accounts for 60% of the total Colombian agricultural exports (Weil, 1970), is grown in

67% of the *municipio* (county) political units (ICA, 1973), and represents 32% of the total value of all crops produced in the country (Economic Research Service, 1973), the salaries and economic security of Coffee Federation employees is superior to that of ICA employees. This attracts some of the best college graduates. At the same time, since 70% of the total number of coffee farms in the country are less than 10 hectares in size (DANE, 1974), this agency has a special commitment to small farmers. The extension activities therefore penetrate all *veredas* (villages) within the coffee region providing an avenue and framework for the transfer of technology.

Although ICA assumed official government responsibility for both agricultural research and extension in 1968 and now manages 11 research centers, 14 experimental stations, and 48 extension agencies (Rochin and Londono, 1975), it has concentrated most of its resources in the 22 integrated rural development projects, which lie outside the coffee growing region. In this way, both institutions complement each other. From the small farmer standpoint, the Coffee Federation clients are for the most part commercially oriented, while ICA focuses on subsistence farmers. However the Coffee Federation initiated a diversification program in 1963 to improve small farm diets, income, and standard of living (Samper, 1967). This program finances crop and livestock enterprises to decrease dependency on one crop (coffee). These include vegetable and fruit crops, livestock, fish farming, beekeeping, and staple food crops such as yuca, plantain, and bean. The Coffee Federation also has research centers such as the Chinchina Experimental Station near Manizales, but in addition it finances rural education and farmer training through a series of *Concentraciones Rurales* (schools).

One such school is the *Concentracion Rural de Julio Fernandez* in the *Municipio de Restrepo* about two hours by car from CIAT. This is a free school for the children of coffee farmers. It combines practical farm training in crops and livestock with primary academic education. It also serves as a center for extension agent and farmer short courses. The Coffee Federation office in the nearby town of Restrepo serves as a headquarters for two extension agents, who also coordinate credit for coffee production through the *Banco Cafetero* and the *Caja Agraria*, and technicians of the diversification program. Part of the office contains a supply warehouse where farmers who belong to the Coffee Federation cooperative can purchase agricultural and building inputs at low subsidized prices.

Very favorable credit terms allow each technical employee of the Coffee Federation to purchase his own vehicle, usually a jeep, which adds tremendous prestige to his position because government import taxes place automobiles beyond the financial means of most Colombians. By supplying gasoline, the Coffee Federation assures the mobility of these technicians with their assigned subregions. As a result, the Coffee Federation has a well-coordinated, mobile staff with a high morale, a credit and input supply infrastructure and the potential to provide continuity for a research effort on small farm bean production. The precise geographical boundaries of the project area correspond to that assigned to the extension agents in Restrepo. This included the *municipios* of Restrepo and Vijes and the surrounding villages as shown in Figures 3 and 4.



Source: *Federacion Nacional de Cafeteros*. 1971. *Mapa de suelos y zonificacion para el cultivo del cafe. Departamento del Valle del Cauca*. Manizales, Colombia.

Figure 3. Location of experimental sites in relation to roads and political units.

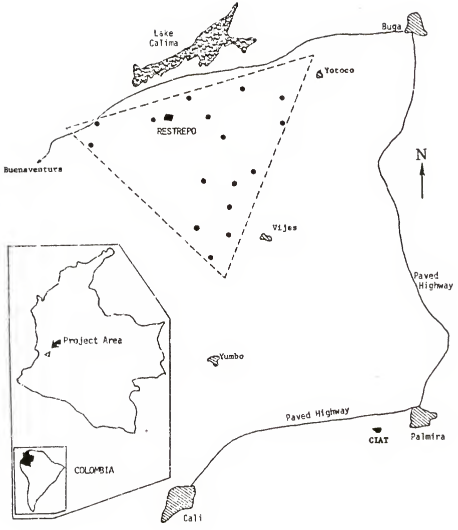


Figure 4. Geographical delineation of the project area.

Setting

The town of Restrepo, which is the central landmark in the project area, lies at 3^0 34' N latitude and $76^0$24' W longitude at an altitude of 1400 meters above sea level in the *Cordillera Occidental*, 58 kilometers from Cali. It is the county seat for the *Municipio de Restrepo* which occupies 135 square kilometers in the *Departamento del Valle*. Restrepo is one of 42 *municipios* in this department which produces coffee. A 1968 survey revealed a population of 12,980 for the entire *municipio* with 654 urban farms and 1213 rural farms (Instituto Geografico Agustin Codazzi, 1974).

The town which was founded in 1913 as Conto and later changed to Restrepo, corresponds to the archdiocese of Palmira, the circuit registry of Cali, and the judicial district of Buga. It contains one church, one bank, one post office, one hospital, one theater, one combination elementary-high school, and two vocational schools. It has electricity, an aquaduct, telephone service to the Cauca Valley, and an outdoor market each Saturday. Unpaved roads lead to La Cumbre, Yotoco, Vijes, Darien, and Dagua, and a six kilometer secondary road exists to the main paved highway to Buenaventura and Buga.

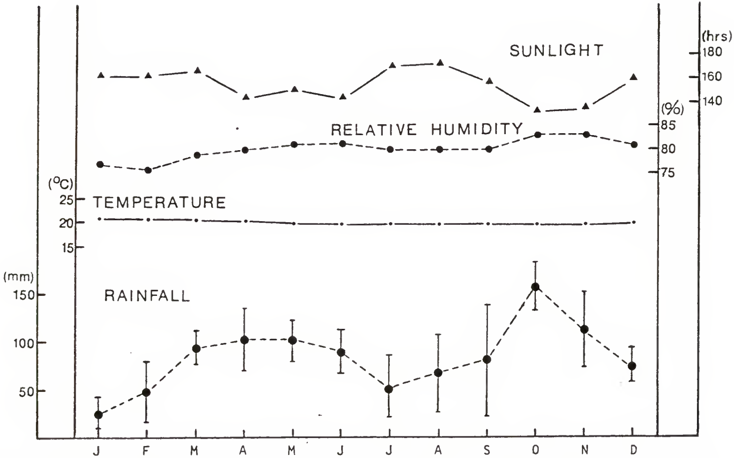
Agriculture is the principal economic activity and coffee leads a long list of important agricultural products which also include maize, banana, plantain, yuca, tobacco, bean, and sugarcane for domestic consumption as *panela* (brown sugar). DANE (1972) reported that 5% of the total arable land in the *municipio* was in permanent crops, 5% in annual crops, 14% in fallow, and 76% in pasture, which supports 7,057 head of cattle. According to the 1970 census, 64.5% of the farms in this

municipio were less than 10 hectares in size, and 47.2% had less than five hectares.

Climate

Climatological data from the *Concentracion Rural de Julio Fernandez* for the year 1973 showed an average annual temperature of 20^{o} C with a range of 12^{o} to 30^{o} C. Figure 5 illustrates the bimodal rainfall pattern in relation to the relatively uniform temperature, relative humidity, and hours of sunlight for the period 1973 through 1976. Wide deviations from mean monthly rainfall during the months of July, August, and September,which correspond to the establishment through early flowering stages for annual crops planted during the second season, make rainfed agriculture risky. A mean annual precipitation of approximately 1,000 mm and 20^{o} C average temperature would place this climate in the "Subtropical Dry Forest" category of the Holdridge Life Zone Classification System (Holdridge, 1967) and the "BA's" category of the Thornwaite System.

The native vegetation of this region includes the following genera: *Alsophila, Aniba, Bocconia, Brunellia, Calathea, Calliandra, Cavendishia, Cecropia, Chaenocephalus, Cinchona, Clusia, Croton, Cyathea, Escalonia, Fagara, Ficus, Hedyshium, Helianthus, Heliconia, Inga, Ladembergia, Miconia, Myrcia, Nectandia, Ochrama, Oreopanax, Pithecellobium, Piper, Rapanea, Rhus, Sapium, Saurauia, Selaginella, Solanum, Theobroma, Tibouchina, Tovomita, Virola, Vochysia,* and *Xanthosoma*. Particularly common are *Ficus chirridiador, Ficus higueron, Ochroma lagopus,* and *Pithecellobium lehmanni* (*Banco de la Republica*, 1964). Some weedy species which are found in crop fields are *Bidens pilosa, Setaria*



Source: CENICAFE. 1973-1977. *Precipitacion en la Zona Cafetera. Avances Tecnicos.* No. 47-50. *Federacion Nacional de Cafeteros de Colombia.* Chinchina, Caldas.

Figure 5. Climatological data (1972-1976) recorded at the *Concentracion Rural de Julio Fernandez* (Restrepo)

geniculata, Amaranthus sp., *Portulaca oleracea, Commelina diftusa, Eclipta alba,* and *Eleusine indica.*

Soils

The municipalities of Restrepo and Vijes contain two major soil series (10 and 200) and a 10-200 complex. The Soil Series 10, which is referred to nominally as the Chinchina Series, comprises approximately one-half of the region's 18,940 hectares, while the Series 200 or Parnaso Series is more widespread in the municipality of Restrepo. A comparison of the characteristics of these two series is presented in Table 3, and their distribution throughout the project area is illustrated in Figure 6.

The Series 10 is of volcanic origin, whereas the Series 200 was derived from the decomposition of basalt igneous rock. This accounts for the superior soil texture and drainage characteristics of the Series 10. Although the Series 10 soils have a higher organic matter and phosphorus content, both soils require supplementary fertilization for optimum agricultural productivity.

Methodology

Philosophy

The overriding objective of this two-year research project was to obtain a proven, low cost technological recipe for increasing bean yields on small coffee farms. The conceptual framework consists of a phased series of on-farm experiments conducted in an atmosphere of inter-institutional collaboration among a research institute, a technical

Table 3. Soil profile characteristics for two soil series (Restrepo, Colombia)

Characteristic	Soil Series 10		Soil Series 200	
	Horizon A	Horizon B	Horizon A	Horizon B
Depth (cms)	0-40	41-55	0-35	36-60
Color	Dark red (10 YR 3/2)	Red (7.5 YR 4/4)	Dark red (5 YR 2/2)	Red (10 YR 5/6)
Texture	Silt loam	Silt loam	Clay loam	Clay loam
Structure	Granular	Granular	Granular	Prismatic
Drainage	Good	Good	Regular	Poor
pH	5.4	5.4	5.6	5.5
Org. Matter (%)	8.8	8.8	6.1	1.0
P (ppm)	7.0	7.0	6.0	3.0
K (meq/100 g)	0.1	0.1	0.5	0.3
Ca (meq/100 g)	1.5	2.0	9.1	11.8
Mg (meq/100 g)	1.6	1.7	9.3	9.6

Source: Fedecafe. 1971. *Estudio de zonificacion y uso potencial del suelo en zona cafetera del departamento del Valle del Cauca. Federacion Nacional de Cafeteros de Colombia.* Bogota, Colombia.

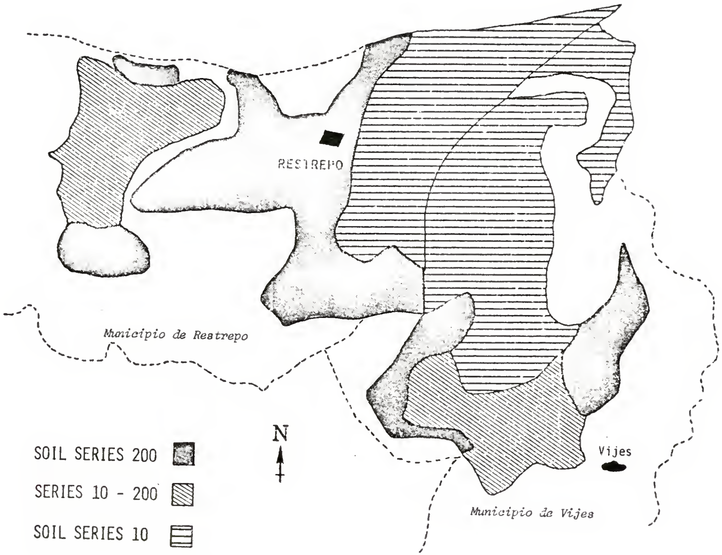


Figure 6. Soil series map (Restrepo).

assistance agency, and a fertilizer company (member of the private sector). The principal underlying assumption in this study is that the application of modern technology to improve the production of staple food crops on small farms has not been successful because technology has not been designed for small farmers. The research apparatus and technical training schools in less-developed countries are structured specifically to serve large-scale commercial farming in an attempt to influence production on a larger proportion of the total farm area.

Students learn about herbicides and tractors long before they hear about the socio-cultural factors which influence the decision-making process on small farms. Experiment stations, located where the soil and climatic factors are most conducive to agricultural production, emphasize yield maximization and the use of expensive inputs in monoculture systems. Small farmers, on the other hand, think in terms of yield stability and a diversified production to minimize risk and dependency on outside agencies (input suppliers, credit banks, marketing organizations, etc.). Small farmers desire to maximize income according to their resource base and the constraints of their production environment, but technology is primarily concerned with maximizing output. Existing technology has not been adopted by small farmers simply because it is incompatible with their production situation.

If small farmers must be treated as a separate entity, how then can technology be customized so that it is productive and profitable in small farm systems and eagerly adopted by small farm operators? Upon whose shoulders falls this responsibility? To answer these questions let us look at the elementary mechanics of agricultural development.

One of the most overlooked components of the simplified agricultural research-extension model (Figure 7) is the validation of technology. Research scientists often view this as the responsibility of extension personnel, while extensionists argue that they have neither the time, money, nor training to do more than demonstrate experiment station recommendations at the regional level. Much of the inadequacy of modern agricultural technology for small farm production can be traced to the gap between research and extension activities. In order to bridge this gap, the model must be reconstructed to include validation as an integral step in the design of appropriate, acceptable, and economically viable technology for the low income, small scale producer. Therefore, the major philosophical pillar of this study is that it is the overlapping responsibility of both research and extension to collaborate in selecting and testing technological alternatives for small farm production.

The bean research program at CIAT, like many national research efforts, is attempting to develop varieties with high-yield potential, which are adapted to specific production environments in the tropics. In the course of this long-term breeding research, an intensive study is made of the interrelated pathological, edaphic, and agronomic bean production problems. The intermediate technology, which results as a by-product of the main research focus, can also make a significant short-term contribution to small farm bean production. Although training programs and short courses for research and extension personnel are the principal means of transferring this information throughout Latin America, direct collaboration with national technical assistance agencies in the validation of technology would assure a more rapid application to small

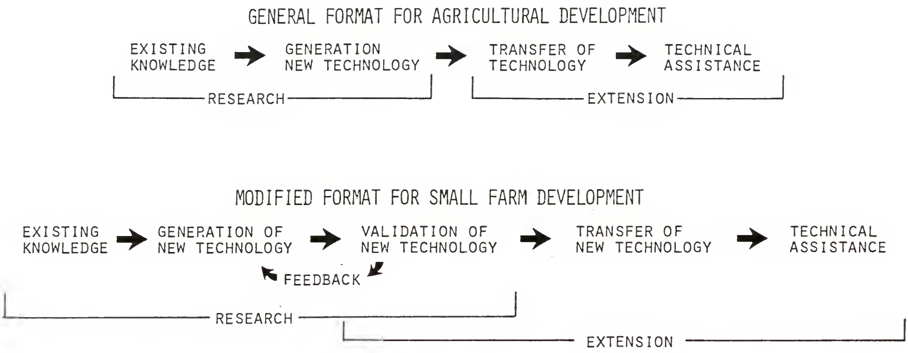


Figure 7. Research-Extension Models for the design and implementation of agricultural technology.

farm production. The Colombian Coffee Federation was seen as an ideal collaborator by which to test this hypothesis, because its clients are organized into readily accessible groups, are familiar with cash crop inputs, and are supplied with the administrative network and credit services necessary to make technological innovations operational and to perpetuate their efforts. The reputable history of this agency also made farmers less suspicious of the author as a foreigner by legitimizing his presence and providing a degree of credibility to his request for their cooperation in on-farm trials.

Farmer participation in the validation of technology in on-farm trials is essential to the philosophy of this study. The synthesis of literature concerning the transfer of technology in small farm development indicates very clearly that actual and "perceived" (anticipated) risk of farmers is the foremost obstacle to adoption. On-farm trials can reduce perceived risk by allowing farmers to closely observe the technology under the rigors of their production environment during several seasons and by allowing them to express their opinions and criticisms to the researchers responsible for seeing that the technology is culturally and economically as well as biologically viable. This feedback mechanism and dialogue between farmer-participant and researcher permits small farmers to become a part of the research project and insures that the technology is appropriate and well-adapted to local conditions. However, recognizing that the tremendous variation in soils and microclimates within a small farm region limits the applicability of site specific research, this study aims toward a core or minimum technology package, which could then be modified according to specific needs of a given site within the project region.

In keeping with the technological package theory of the Green Revolution, this study attempts to isolate a superior variety and build a package of complementary agro-chemical inputs around it. These inputs would be carefully selected on the basis of their relative costs and availability to overcome the principal limiting factors in the production environment in order to realize the genetic yield potential of the new variety. This low cost, minimum input strategy is again in line with previously documented small farm development experiences concerning the trade-off between technological innovations which result in impressive yields and those with a high adoption rate. In general there appears to be a strong relationship between the potential improvement in net income and adoption. A similar relationship exists between adoption and the degree of divergence from tradition which the innovation requires. In most cases, innovations which demand large cash outlays for purchased inputs or a radically different pattern of cultural practices have not been acceptable. The question is therefore not how high can small farm yields be increased or how much can small farm yields be brought up to the level of experiment station yields, but rather what feasible yield increase can be attained, given the farmer capital and resource situation, to give a significant increase in income. Although demonstrations of experiment station recommendations in less-developed countries repeatedly have shown that large yield increases are agronomically possible on small farms, acceptance will be determined in the final analysis by economic evaluation.

Components

This study attempts to bridge the isolated realms of research and extension by bringing experimentation to the farm level. The methodology

can be broken down into three component phases: observation, technological package design, and economic evaluation. When considered within the context of the 22-month period alloted to the field research, four stages, each corresponding to one growing season, are evident (Figure 8). The design phase is thus divided into two segments, one for screening new varieties and the other for determining the major agronomic limiting factors.

In the observation phase of the study, an effort was made to obtain a better understanding of the small farm production environment in the project region and the factors which influence decision-making behavior. The Puebla Project prototype for acquiring this information involves expensive, time-consuming, in-depth socioeconomic surveys, such as those conducted on 600 farms in the Caqueza Project near Bogota and on 140 farms in the Cauca Integrated Rural Development Project near Cali. However, the dividing line between essential baseline information and information for luxury academic consumption remains to be determined. In keeping more in character with the agronomic nature of this study, the orientation stage focused on the traditional bean production system and its associated socioeconomic infrastructure as illustrated in Figures 9 and 10.

Although it may appear contrary to the philosophy of projects aimed at the rural poor, the consensus of opinion in the small farm development literature is that the validation and transfer of technology focus on the most progressive small farmers in a region. These farmers are usually local leaders whose income is slightly above average because of their finesse in cash cropping. The theoretical assumption is that their neighbors who are less cooperative and less willing or able to

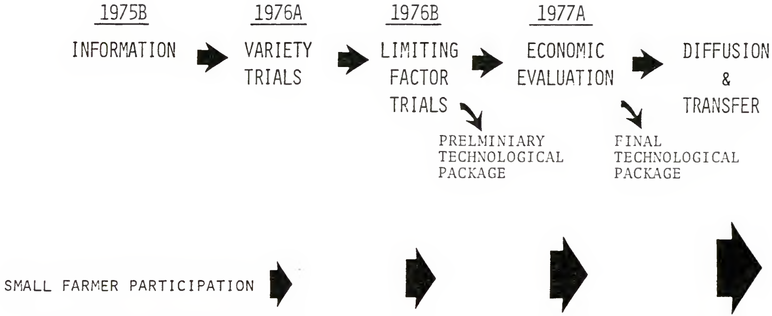


Figure 8. Thesis methodology for formulation of a bean (*Phaseolus vulgaris* L.) production technological package for small farmers.

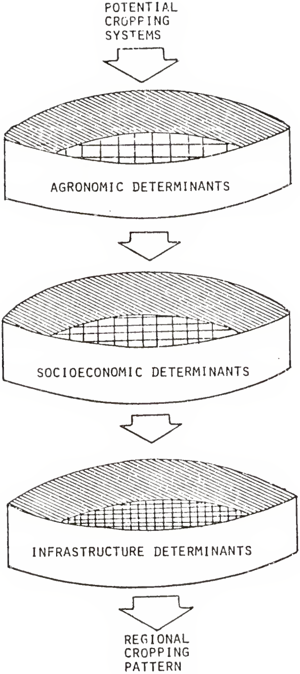


Figure 9. Factors which determine crop production.

AGRONOMIC DETERMINANTS OF CROP PRODUCTION

1. PHYSICAL FACTORS (TOPOGRAPHY, ALTITUDE, SOIL TEXTURE AND FERTILITY)
2. CLIMATIC FACTORS (TEMPERATURE, RAINFALL, RELATIVE HUMIDITY)
3. BIOLOGICAL FACTORS (CROP GERMPLASM, DISEASES, INSECTS, WEEDS)

SOCIOECONOMIC DETERMINATIONS OF CROP PRODUCTION

1. CONSUMER PREFERENCE (COLOR, COOKING QUALITIES)
2. MAN:LAND RATIO (POPULATION DENSITY)
3. LAND TENURE AND LAND DISTRIBUTION
4. PATTERN OF LABOR UTILIZATION (PERIODS OF UNDEREMPLOYMENT, UNEMPLOYMENT RATE)
5. HEALTH AND NUTRITIONAL STATUS
6. INCOME LEVELS (RURAL VS URBAN, FARM VS NON-FARM, WAGE RATES FOR DAY LABOR)
7. PRICE FLUCTUATIONS FOR INPUTS AND AGRICULTURAL COMMODITIES)

INFRASTRUCTURE AND INSTITUTIONAL DETERMINANTS OF CROP PRODUCTION

1. CREDIT AVAILABILITY AND COST
2. MARKETING STRUCTURE AND POST-HARVEST STORAGE FACILITIES
3. TECHNICAL ASSISTANCE (VIABLE EXTENSION SERVICE)
4. EDUCATIONAL SYSTEM (LITERACY)
5. TAX STRUCTURE
6. TRANSPORT SYSTEM (VEHICLE AVAILABILITY, ROAD CONDITIONS)
7. PRICE SUPPORT SYSTEM

Figure 10. Baseline information for understanding a crop production system.

take risks will imitate the success of their leaders and thereby benefit by the technology in the long run. Progressive farmers are also reliable sources of information. Therefore,an effort was made to cultivate a friendship with these farmers during the first stage of the study and to conduct trials on their farms in the following stages.

To supplement information obtained from direct contact with farmers and extensionists during the observation phase of the study, third stage research trials were undertaken to quantify the relative agronomic importance of the limiting factors in bean production. This methodological component was included because farmers are often mistaken as to why crops fail, attributing, for example, devasting bacterial blight damage to weather abnormalities. Consequently, it was felt that some combination of survey information and experimental data was necessary on which to formulate the complementary agrochemical inputs of the package. The optimum levels of these inputs from an economic standpoint was determined in the final stage of the study. Trials conducted with farmer groups in the third and fourth stages served to test the preliminary ingredients of the package more widely throughout the region and to expose more farmers to the bean yield improvement research project.

Stage 1

The essential baseline information gathered at the onset of this study was obtained by three methods: personal observation, a 10-farm sample, and Coffee Federation literature. In order to observe the traditional production system more closely and to become acquainted with both the extension personnel and the farming group leaders, two types of

unreplicated on-farm experiments were initiated. The first type involved the introduction of commercial maize (H302) and bush bean ('Calima') varieties on five farms which were selected by the local extension agent. On the other five farms, the CIMMYT opaque maize variety (VE21) and a CIAT bean accession ('Pompadour'), which had looked exceptionally promising in varietal trials at an elevation of 1,000 meters in the Cauca Valley and at 1,800 meters near Popayan, were planted. The quantity of seed of each variety was sufficient to plant an area of 50 m^2 at commercial planting densities. At maturity each trial was harvested by hand and yield estimates, adjusted to 14 and 15 percent moisture content for bean and maize, respectively, were based on the production of the bordered 24 m^2 experimental area. Yield component data were based on 10 plant samples. These trials gave the author an excuse for returning periodically throughout the growing season to talk with the farmer and to note his production practices. At the end of the season, a simple survey (Appendix A) was administered to these 10 farmers.

Stage 2

The goals of the varietal screening stage were threefold. The first objective was to select varieties with the highest yield potential for the conditions of the project area. Secondly it was necessary to evaluate genotype by technology and genotype by system interactions. The final objective was to stimulate farmer interest in improved varieties of staple food crops. One of the hypotheses of this stage is that it is not possible to select varieties at optimum technological levels for traditional technology systems. A second hypothesis is that it is not possible to

select varieties under monoculture conditions for intercropping systems. To test these hypotheses eight field trials were planted on seven farms.

The bush bean varieties selected for initial screening were chosen on the basis of yield performance in four regions of Colombia (Table 4). Since similar information was not available for climbing bean varieties, fewer climbing bean varieties were examined. However, the same spectrum of bean colors was represented in both bean types. Local varieties of each type were also included as a reference point by which to measure yield increases.

The two technology treatments differed in respect to plant density, plant spatial arrangement, fertilizer level, and the utilization of a granulated systemic insecticide. These treatments therefore simulated the typical small farm production system as observed in the previous season and a modified traditional system, in which the plant population density was optimized and chemical rather than organic fertilizer was used. Hand weeding and disease control were uniform in both treatments. Three applications of a locally available, relatively inexpensive fungicide and two manual weeding operations were conducted. The granulated systemic insecticide was utilized because it was effective against a range of insects, was locally available and known by the farmers, and could be easily applied by small farmers without the toxic hazards inherent in other insecticide formulations.

Seed of a local maize variety was purchased in the town of Restrepo and utilized in the intercrop system at the recommended density of 4 plants/m^2 (Francis et al., 1976a; CIAT, 1976b). The spatial arrangement

Table 4. Regional yield summaries† for bush bean varieties used in Stage 2 experiments.

CIAT accession number	Location				Mean	C.V.	Country of origen	Color	Variety name
	CIAT	Popayan	Loboguerrero	Restrepo					
	------------metric tons/ha				------------	%			
P459C	2.01	0.78	2.42	1.99	1.80	39	Venezuela	black	Jamapa
P302A	2.01	0.74	2.74	1.60	1.77	47	Mexico	black	---
P458C	1.69	--	2.59	2.01	2.10	23	Colombia	black	ICA Tui
P524A	1.55	0.96	1.76	1.69	1.49	24	Costa Rica	cream	---
P756A	1.79	0.52	1.43	1.45	1.30	42	Brazil	white	Rico 23
P643A	1.52	0.80	1.50	1.58	1.35	27	Costa Rica	white	Nep 2
P637A	1.53	0.97	2.54	--	1.68	47	Colombia	red	Line 17
P758B	2.14	0.94	2.26	1.61	1.74	35	Mexico	brown	Puebla 152
P692A	1.93	0.72	2.44	--	1.70	52	Colombia	red	Calima

† These high input trials included 25 bush bean varieties at each location.

and spacing of plants in both systems is illustrated in Figures 11 and 12. An attempt was made to change as few of the components of the traditional system as possible in the course of adapting the variety, density, and fertilization factors. For this reason, the same row spacing was maintained in each technology treatment level. Optimum population densities were therefore achieved by manipulating the within-row spacing. Bamboo branches, which had no prior economic value and which were only occasionally used in makeshift fences, served as the supports for monoculture climbing beans. Bamboo is a common resource in the area and found on most small farms. In this way, the limitation of an expensive support apparatus for monoculture climbing beans, which had been encountered in CIAT, was avoided, and costs were kept well within the range of those normally involved in small farm bean production.

Since this experiment was to be established on small farms where land area is limited, a minimal plot size (3 x 4 meters) and only three replications of each treatment were used. To maximize the experimental area of these small plots, bean varieties were grouped by plant type and plots were closely aligned in blocks with one border row planted on each end of the block as shown in Figure 13. In effect, this arrangement eliminated the need for border areas along the sides of the individual plots. However, a 50 cm border was discounted from the ends of each plot, allowing a total of 9 m^2 of experimental area per plot. The original intention was to establish one trial in the municipality of Restrepo and another in the municipality of Vijes because the soils and micro-climates of these two regions differ. However, the experiment was too large to place on a single farm. For this reason, the experiment was

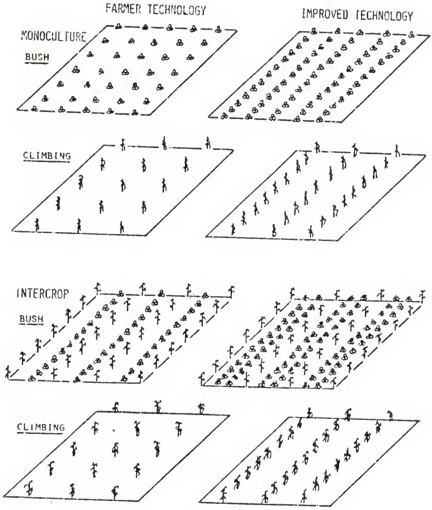


Figure 11. A comparison of planting arrangements for two bean types at two levels of technology.

CULTURAL PRACTICE		TECHNOLOGY TRADITIONAL	TECHNOLOGY IMPROVED
DENSITY	BUSH	11 pl/m^2	25 pl/m^2
	CLIMBING	3 pl/m^2	15 pl/m^2
FERTILIZER		Organic (2T/ha)	13-26-4 (200 kg/ha)
INSECT CONTROL		--------Foliar--------	--------Foliar--------
			Furadan

Figure 12. Contrasting characteristics of two technology treatments.

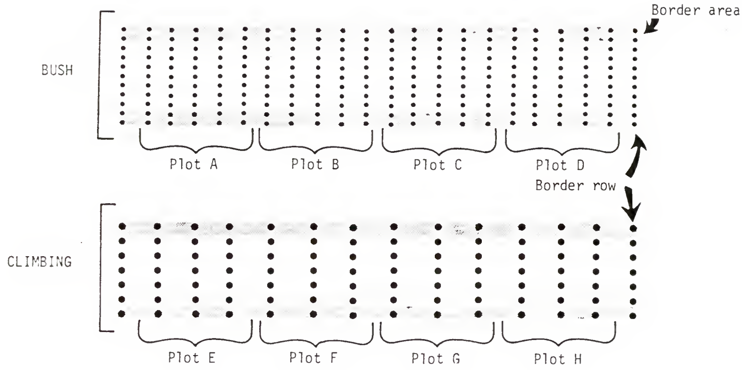


Figure 13. Planting arrangement to minimize unessential border areas.

subdivided by bean type and by planting system into four smaller trials, each of which could fit on a small farm. Therefore, instead of one experiment repeated in two zones, the research in this stage of the study evolved into a total of eight experiments. In one instance, enough available land was found on one farm for the establishment of two of these trials, which explains why only seven farms were used.

At maturity, the 9 m^2 experimental area of each plot was harvested by hand and placed in labeled burlap bags for transport to the CIAT laboratory to determine yields. The moisture content of 250 grams of beans was measured, and bean yields were subsequently adjusted to 14% moisture. Whole bush bean plants were harvested, but because of the difficulty of separating climbing bean vines from their supports it was more convenient to harvest only climbing bean pods. Subsampling to measure yield components also varied by bean plant type. A 10-plant sample of whole bush bean plants were used in the measurement of plant height and the number of pods per plant. The dryness and brittleness of the climbing bean plants at harvest necessitated a field measurement of these same yield components in climbing beans. However, 10 pods were used in both plant types to determine the number of beans per pod.

During the design of these experiments, consideration was given to the minimal sample size, which could be used with confidence to measure population density and yield components. To satisfy doubts and further refine the experimental procedure in later stages of the study, subsamples were taken at the harvest of a nine variety, bush bean, monoculture trial and the coefficient of variation was calculated for each of five sample sizes. For plant density determinations, the number of plants was counted

in 1, 5, 10, 15, and 20 meters of row for each plot. Subsamples of 1, 5, 10, 15, and 20 plants were then harvested to measure the number of pods per plant, and from these plants samples of 1, 5, 10, 15 and 20 pods were randomly selected to determine the number of beans per pod.

In addition to these eight on-farm experiments, seed of various maize, bean, and yuca varieties was given to the farming groups (*Grupos de Amistad*) organized by the Coffee Federation. These group demonstration trials were to be planted, managed, and evaluated by the farmers themselves in conjunction with the local extension agent. Since the concept of varietal improvement is fundamental to the "package of technology" approach, the purpose of these demonstrations was to stimulate interest in new varieties of food crops. At the same time, these demonstrations open the door to the more active farmer involvement in later stages of the study.

The varieties distributed to each farming group included three bush bean varieties (P458, P524, P643) and three climbing bean varieties (P525, P589, P364). The beans of these varieties are black, cream, and white, respectively. Four maize varieties and a yuca variety were also included. Two of the maize varieties were commercial hybrids (H302, H207). The third was a brachytic dwarf yellow variety (Br2-C74B), and the fourth was a CIMMYT hard endosperm yellow opaque variety (VER181-Ant. GP02 X PR73B Ven. 1. Opaco 2). Since the yuca program at CIAT is concentrating on the lowland tropics, only one CIAT yuca variety ('Popoyan') was applicable to the project region. This variety while similar to local varieties in yield and growth pattern is resistant to the pathogen *Phoma* sp., which can be very destructive under cool, moist conditions. Farmers

were instructed to plant their local bean, maize, and yuca varieties alongside the demonstration varieties for comparison, and to manage all varieties as they were accustomed.

Stage 3

The principal objective of the third stage was to determine the relative importance of the major factors limiting bean production in the project area. Quantifying the priority ranking of the agronomic production factors provides the necessary information on which to base decisions in the selection of the agrochemical inputs to complement the varietal component of the package. On-farm trials of this nature also help farmers to understand the interrelated factors in crop production and the need for agrochemical inputs. However, the strong small farmer preference for red bean varieties evident in the previous stage of the study, dictated a further effort to isolate yield potential specifically in red bean varieties. This follows the premise that it is easier to change varieties than it is to change consumer appeal and marketing standards.

Two types of limiting factor trials were undertaken. The first involved replicated treatments with both bush and climbing bean types in two planting systems. Because of the site specificity of these studies, unreplicated experiments were also established with each farming group. In this case each farming group was considered a replication of a single experiment which covered the entire region. In spite of the fact that the responsibility for establishing and managing these trials was given to the farmers and the local extension agents, harvesting and sampling was performed by the author.

There are many agronomic aspects of bean production which could have been studied as treatments in these experiments. Among these are: clean seed or seed treatment, plant population density and spatial arrangement, fertilization, irrigation, pest control, and management variables (planting date, land preparation, crop rotation, and the kind, amount, and number of input applications). The factors of clean seed and irrigation were not considered, because they were not available to small farmers in the project region. However, planting densities in the traditional bean production system were far below optimum levels, phosphorus and micro-nutrient deficiencies were known to exist throughout the project region, and heavy disease infestations had been observed. Therefore, the relative importance of the following bean production factors was evaluated in monoculture and in association with maize.

Factors Studied

- Variety
- Planting Density
- Fertilization
- Insect Control
- Disease Control

Factor Levels

- Varieties
  - Local red bean variety
  - Introduced black bean variety
- Planting Density
  - Traditional planting density
  - Optimum planting density

Fertilization

None

Complete

Insect Control

None

Complete

Disease Control

None

Complete

Treatments

Complete Technology (Introduced black bean variety)

Complete Technology (Local red bean variety)

Complete Technology (Introduced variety) using traditional planting density

Complete Technology (Introduced variety) without fertilization

Complete Technology (Introduced variety) without insect control

Complete Technology (Introduced variety) without disease control

Farmer's Technology (Local red bean variety)

The black bean varieties ('ICA Tui' and P525) which had excelled in the previous season were used to quantify the importance of the varietal factor. The planting densities for the two bean types in both systems is shown in Table 5. In order to assure an adequate supply of all required nutrients, the traditional fertilization practices (chicken manure @ 1 ton/ha) were supplemented with 200 kg/ha of a complete chemical fertilizer with a high phosphorus analysis (13-26-4) and foliar application

Table 5. Planting densities for bush and climbing bean varieties in the Limiting Factor Trials (Stage 3).

Treatment	Monoculture	Intercrop
	------------pl/m^2------------	
Bush		
Complete (C)	24.9	25.3
C - Density	12.4	12.6
Farmer tech.	12.4	12.5
Climbing		
Complete (C)	12.5	12.3
C - Density	6.3	6.3
Farmer tech.	3.3	3.3

of the two limiting micronutrients (zinc and boron). Wettable powder formulations of $ZnSO_4$ (50 g/12 liters H_2O) and Solubor (30 g/12 liters H_2O) were combined in manually operated back sprayers with the fungicides Dithane M45, Koccide, and Benlate and the chemical adherent (Triton) at the recommended rates. This mixture was applied 14, 25, 35, and 45 days after germination. The $ZnSO_4$ and Solubor solution was first applied to the "complete technology minus disease control" treatment. Then the fungicides were added and the remaining treatments fumigated. Insect control was accomplished by the use of 30 kg/ha of the systemic insecticide Furadan. The "complete technology with the introduced variety" treatment serves as the control for this experiment, and subsequent treatment yields are expressed as percentages of this optimum treatment yield. On the other hand, the "farmer's technology" treatment functions only as a baseline for demonstration purposes in the field.

A second series of trials concerned with application of this experiment on a regional or multi-location level, in which each group of farmers conducted a replication of this study in their village (*vereda*). The factors studied and the individual treatments were identical to the two larger experiments which were replicated in the same field, however these group trials involved only bush beans in monoculture. In this case, the seed, inputs, and planting diagram (Appendix B) were given to each farming group by the local extension agent and planted on accessible land donated by a group member. Aside from harvesting and sampling, all management aspects of the trial were the responsibility of the farmers themselves. Since most beans are planted in the region within a one or

two week period, by delegating the responsibility for planting and overseeing these experiments to the local farmers, the author was able to concentrate on the larger limiting factor and varietal screening experiments. This was also a test of the farmer's competence in handling experiments.

Experiences in the introduction of new rice varieties in Asia (IRRI, 1974) and maize varieties in Colombia (Andersen, 1971) indicate that new high yielding varieties, whose grain characteristics (color, cooking qualities, flavor, etc.) differ greatly from those of local varieties, have a low adoption potential. In order to maximize the adoption potential of the varieties selected in this study and insure their marketability, the third stage of this study also included four red bean varietal screening trials at two locations. The most promising bush and climbing red bean varieties from CIAT's bean germplasm collection were analyzed in replicated trials under optimum fertility and pest control conditions. In addition to 200 kg/ha of 13-26-4 and one ton/ha of chicken manure, 30 kg/ha of the systemic insecticide, Furadan, was applied at planting. The fungicides Dithane M45, Benlate, and Koccide were combined with $ZnSO_4$ and Solubor in four applications at 15, 25, 35, and 45 days after planting. Plot size, sampling procedure, and plant spacings were identical to those used in second stage experiments. Monoculture population densities of 25 and 12 plants/m^2 were used for bush and climbing bean types, respectively. Bamboo branches were again used to support the climbing bean varieties. The local red bean varieties of each type served as controls for each experiment with the three best non-red varietal selections from the previous season. The varieties studied were:

Bush beans		Climbing beans	
Line 20738	(red)	P103	(red)
P221	(red)	P82	(red)
P130	(red)	S118	(red)
P45	(red)	S220	(red)
P132	(red)	P50	(red)
P124	(red)	Radical	(red)
P169	(red)	P525	(black)
P87	(red)	P364	(white)
P366	(red)	P589	(cream)
P141	(red)		
Calima	(red)		
P458	(black)		
P643	(white)		
P524	(cream)		

Stage 4

In the final stage of this study, two types of experiments were undertaken. The first group of four replicated experiments attempted to determine the economically and agronomically optimum input level of phosphorus for bush and climbing bean varieties of several bean colors. This study was modified in the second series of experiments to demonstrate and validate the preliminary technological package in multi-location farmer group trials. Only the highest yielding red bean varieties of both bush and climbing bean types were used in these farmer group trials to maximize potential acceptability. The experimental components of the Phosphorus Level Trials included:

Factors Studied

Varieties (9)

Phosphorus quantities (4)

Factor Levels

Varieties

Bush beans

P366 (red)

P124 (red)

Calima (red)

P458 (black)

P643 (white)

Climbing beans

P103 (red)

S220 (red)

P525 (black)

P364 (white)

Phosphorus quantities

50 kg P_2O_5/ha

100 kg P_2O_5/ha

150 kg P_2O_5/ha

200 kg P_2O_5/ha

Experimental results from CIAT have suggested a bean color variety by phosphorus interaction. To explore this further, the phosphorus treatmentswere applied to the two best red and non-red varieties of both bean types, which had been selected earlier in the study. The local red bean variety was also included in the bush bean experiments.

Because of the differences in soil characteristics and micro-climates between the municipalities of Restrepo and Vijes, one complete experiment was established in each zone. However the size of the complete experiment in comparison to the area available on any given small farm required that the experiment be subdivided by bean type. This resulted in four experiments on four farms.

Concentrated triple superphosphate (46% P_2O_5) was the phosphorus source utilized in these experiments. Although this is the most expensive of the available phosphorus sources, it is the easiest to handle experimentally from a bulk standpoint. Simple superphosphate (20% P_2O_5) which is one of the cheapest phosphorus sources was inappropriate because it contains 12% sulfur and would therefore introduce another variable. The minimum 50 kg P_2O_5/ha phosphorus level was based on soil fertility and economic feasibility considerations. This level corresponds to that used in earlier stages of the study (i.e. 200 kg/ha of 13-26-4).

The experimental procedure, pest control, and optimum monoculture population densities were the same as those described for experiments in previous stages of this study. The compounds $ZnSO_4$ and Solubor were again combined in the four fungicide applications. Since the randomization and replication of these phosphorus level trials tend to obstruct farmer comprehension of treatment comparisons, a second group of trials was designed to facilitate farmer participation and understanding. At the same time, the farmer group trials provided additional information on the performance of CIAT red bean varieties throughout the project area during another season.

Seed of five red bean varieties, fungicides, triple superphosphate, and a planting diagram (Appendix C) were given to each farming group and explained by the local extension agent. The amount of seed and phosphorus necessary for each individual 3 x 4 meter plot was placed in a separate plastic bag, whereas the fungicides were measured and bagged according to the amount necessary to fumigate the entire six plot experiment at one time. The farmer group trials involved three bush bean varieties (P366, P124, and Calima) and two climbing bean varieties (P103 and S220). One plot of each variety was planted and fertilized at the rate of 50 kg P_2O_5/ha. An additional control plot of Calima was planted and fertilized with chicken manure in the traditional manner.

Unlike the farmer group trials of the previous seasons, in which the yield component determinations were made in the laboratory at CIAT, an attempt was made to leave as much seed as possible of these promising red bean varieties with the members of the farmer groups. Since this stage was the culmination of the study, in this way the farmer participants would have at least some physical benefit of the study in their hands. They could then further test these promising varieties on their own farms and multiply seed of any variety that particularly suited their preferences and requirements. To accomplish this objective, yield component measurements were made in the field using the sampling procedure previously described, while yield determinations were made by harvesting one three-meter length of row in the center of each plot.

Analytical Procedure

All yield component and yield data were analyzed through an IBM Model 3705 Programmable Communications Controller and an Amdahl 470 V/6 II computer using the Statistical Analysis System (Barr et al., 1976). Analysis of Variance and Duncan's Multiple Range Tests were used to determine significant differences among treatments. The General Linear Models Procedure was used in calculating the least squares fit of yield by density data and in univariate regression analyses for determining optimum sample sizes.

The comparison of varietal yield stability utilized the method proposed by Eberhart and Russell (1966). This involves the stratification of environments and the regression of the yield of each variety on this environmental index. However, one aspect of an earlier method (Finlay and Wilkinson, 1963) was also incorporated in the analysis to provide a more general interpretation of varietal adaptation. Although the regression techniques are similar in both cases, the latter method measures yields on a logarithmic scale. The regression coefficients are then plotted against the mean yields of all varieties at a given site.

The Spearman Rank Correlation method, as discussed by Steel and Torrie (1960), was used to analyze a range of varieties in different planting systems and at different levels of technology. In an attempt to quantify and rank bean color preference, Paired Comparison Tests involving nine bean colors were administered to eight farmers, two housewives, and a local grain merchant. This test is a sequential comparison of each variable with all other variables as shown in Appendix E. During this survey, farmers were also asked to place three varieties, whose beans differed in size but not color, in order of preference.

RESULTS AND DISCUSSION

Stage 1

The Site: An Overview

Observations made during the first six weeks of this study in a general reconnaissance of the municipalities of Restrepo and Vijes were encouraging. The geographical and climatic characteristics of the region suggested a potential transferability of results to other small farm areas of Latin America. The transport system, credit and input availability, and technical assistance infrastructure were considerably above average for comparable rural districts. From a logistical standpoint, the region was relatively close to the CIAT station and all *veredas* were readily accessible throughout the year by a four-wheel-drive vehicle. This permitted visits by production specialists and other CIAT personnel to consult on problems and to observe CIAT technology in a small farm environment.

The predominance of commercial coffee production in the region serves to integrate coffee farms of all sizes into the national economy. Since coffee is a renewable national resource of considerable value on the export market, coffee farmers have gained government respect and attention. As a result, these farmers are a unique group and a dynamic social class in Colombia. Even the managers of coffee enterprises on small holdings have a sense of national importance and power, and their political stature has been further enhanced by the historical notoriety of Restrepo

during the *Violencia* period of civil disorders, which shaped the political organization of present day Colombia.

Contrary to the common stereotype of small farmers in traditional agriculture, farmers in the project area displayed a progressive attitude and widespread enthusiasm for the improvement of basic food crop production. The national Coffee Federation had been actively supporting the diversification of coffee farms with projects in tomato, pineapple, fruit crop, fish farming, and beekeeping enterprises, but little, if any, effort had been devoted to yuca, maize, and bean. On a smaller and less significant scale, the *Secretaria de Desarrollo y Fomento* of the Ministry of Agriculture was involved in the improvement of dairy and beef cattle operations. The author's study to increase bean yields on small coffee farms therefore did not overlap or interfere with any on-going extension activities and was welcomed as a new armament in a collective campaign to improve the well-being of coffee farmers.

Bean Germplasm

Beans were a particularly good crop on which to base a study in this region because they were of both commercial and subsistence value for small farmers. The red bean market price is four times greater than that of maize, and several regional dishes (e.g. *Frijoles con Garra*) include beans. Bush bean varieties were an ideal short cycle, intercrop for coffee during the establishment phase to efficiently utilize available land area and to recover some of the establishment costs of the perennial crop. The high price of coffee on the world market in 1976 renewed interest in the expansion of coffee acreage and the renovation of old coffee stands, thus stimulating a special interest in beans. At

the same time, commercial, monoculture, bush bean production occupying several hectares was observed on larger farms in rotation with other crops, while mixed cropping of bean with maize, yuca, banana, coffee, and fruit trees typified small farm production.

The commercial red bean variety (Diacol Calima), which is produced on both large and small farms in the region, was developed by the *Instituto Colombiano Agropecuario* (ICA) in the late 1960s as part of the legume genetic improvement program. Information from ICA (Orozco, 1973) reports that under experimental conditions this variety produced 1,800 kg/ha in 87 days when grown at elevations from 800 to 1,200 meters above sea level. ICA has released other improved varieties for specific altitudes within a range of 800 to 2,600 meters, but Diacol Calima has been the greatest commercial success. It is a large seeded variety, which tolerates both Rust (*Uromyces phaseoli*) and Angular Leaf Spot (*Isariopsis griseola*) diseases. ICA also developed a black seeded bush bean variety (ICA Tui) which is grown commercially on large mechanized farms in the Cauca Valley for export. However, Orozco emphasized that 85% of the bean production in Colombia occurs on farms which range in size from 0.8 to 10.0 hectares. These farms employ traditional production techniques and are located at elevations above 1,200 meters.

Although local climbing bean varieties exist in the region, they are used primarily for domestic consumption and enter the market on a very limited scale. This is due in part to the characteristics of the local variety. Vigorous and excessive vegetative growth demands a very strong support, such as a fence post or dead tree. The long flowering period necessitates repeated harvests over several weeks, and the final product

contains a wide range of bean colors. A sample of the local climbing bean variety, Radical, which was purchased in Restrepo, was found to contain seven distinct varieties. The six additional varieties comprised one-third of the total sample. Using several varieties of each crop and several crops in the same field are safeguards employed by small farmers to reduce production risk and the possibility of complete crop failure.

One of the major objectives of the Bean Program at CIAT, which began operation in 1974, is the characterization of bean germplasm. The germplasm collection, which numbered 10,000 entries in September of 1975, increased to over 14,000 entries by June of 1977. An active hybridization program with 85 parents produced 35,400 F_1 and F_2 field tested progeny in 12 months (CIAT, 1976b). From this analysis and genetic manipulation of the bean germplasm resource, 796 promising varieties were selected. The important agronomic characteristics of these varieties were recorded on a computer recall system. The majority (82.8%) of these promising varieties were one color, and 51.6% were black bean varieties (Table 6). Approximately 10% were pink, red, and purple. Most (59%) of the promising varieties had small seeds, and only 17.2% were climbing beans. Therefore, from the standpoint of improving small farm bean productivity in this study by the use of improved varieties with high yield potential, the available technology consisted primarily of small, black seeded, bush bean varieties.

Settlement Patterns

Colonization of the project area, then under subtropical forest, began some 50 years ago with the majority of new farmers coming from the

Table 6. Distribution of 796 promising bean varieties by color†.

Bean Color	Bush bean	Climbing bean	Total
	-------------	%	-------------
White	12.6	14.8	12.6
Cream or Yellow	6.5	10.4	6.5
Reddish brown	14.2	14.8	14.2
Brown	4.5	2.6	4.5
Pink	1.1	1.7	1.1
Red	6.8	7.8	6.8
Purple	1.5	1.7	1.5
Gray	0.3	0.0	0.3
Black	52.5	46.1	51.6

† Refers to varieties whose beans are only one color.

department of Antioquia. Infiltration has also occurred more recently from the departments of Valle and Cauca in response to the completion of the paved highways from Buga and Cali to Buenaventura. The discovery of gold and ceramic figurines (*guacas*) in Indian burial sites around Restrepo undoubtedly attracted some people to the area, because Indian pottery and gold artifacts, particularly from the Quimbaya archeological region, bring high prices from national museums. Town merchants serve as middlemen in negotiations between *guaceros* who locate and uncover grave sites, and potential buyers from outside the village. However the lucrative discoveries have become less frequent over the years as colonization has spread throughout the region. Farmers now collaborate with *guaceros* by providing right of access to their land. If successful, both parties will split the earnings. Although the search for and exploitation of archeological findings continues today as in the past, the vast majority of the colonists came to the region as homesteaders. As in human migrations elsewhere, these colonists brought with them seed, tools, and a concept of agriculture as it had been practiced in their area of origin.

Commercial Coffee Production

Information from the Coffee Federation indicates that coffee was first introduced into the Valle Department at the turn of the century from the departments of Antioquia, Caldas, and Tolima. From 5,931 hectares of coffee in 1926, the acreage grew to cover 126,775 hectares on 17,116 farms by 1970 (DANE, 1974). The Valle Department now supplies approximately 14% of the national production of coffee. However since only 15% of the surface area is conducive to coffee production, the

coffee region is concentrated on the mountain slopes, which line both sides of the Cauca Valley. Of the 42 counties producing coffee in the Valle Department, Restrepo ranks twentieth in coffee production. As might be expected, there is considerable competition for recognition and resource allocation between the Coffee Federation personnel in the various counties. Exceptionally high coffee prices during the course of this study resulted in a large effort to extend the coffee acreage in Restrepo and thereby improve its ranking relative to other counties in the department.

Coffee Infrastructure

The Coffee Federation was created in 1927 to assure a market for producers, to provide credit and storage facilities, to represent and protect the interests of the small producers at the national level, and to handle coffee exports. Colombia is the second leading exporter of coffee in the world, supplying 13% of the world coffee exports (Weil, 1970). Of the 627,356 tons of coffee produced in Colombia in 1970, 81.9% was exported. Aside from being a major source of foreign exchange (60% of the total exports), coffee is the main production enterprise of over 300,000 Colombian farms and represents 25% of the total farm output of the country. The Coffee Federation purchases approximately 70% of national coffee production, charging a 19% coffee retention tax on earnings to finance buying and storing. The Coffee Federation also administers a price stabilization program through a cohesive credit-input cooperative to buffer the effect of fluctuating world coffee prices. Although the level of the support prices is usually below anticipated open market prices, credit contracts stipulate that cooperative members

must sell to the Federation. When the world market prices are high, large farm operators, who are not dependent on the Federation for credit or subsidized inputs, realize a substantially greater profit than do members of the Federation. Nevertheless, support prices are high enough to cover the small farm production costs and allow a profit.

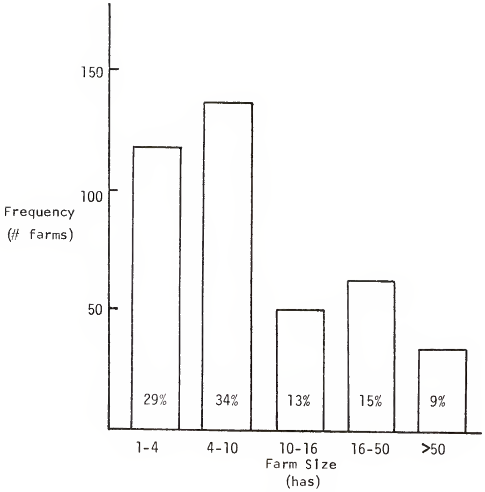
The *Banco Cafetero* (Coffee Bank) was formed in 1953 by the Coffee Federation, which is the sole stockholder, to finance the production, transport, and exportation of coffee, and to assist in the general development of coffee zones. In 1971, the bank had 176 agencies spread throughout Colombian coffee-growing regions. Two other historical developments which pertain to this study deserve mentioning. The first concerns the *Fondo Rotatorio de Credito*, which is a rotating credit fund established in 1960 to finance development activities. This is the financial basis of the Committee for Development and Diversification of Coffee Zones, which began operations in 1963 to improve the standard of living of coffee producers (Samper, 1967). In order to reduce the dependence on coffee and stabilize incomes and labor use, this committee administers technical assistance in field crops, forestry, fruit crops, and livestock production. These projects are especially beneficial to small farmers where diversified productivity is the key to higher incomes and lower risk. At the same time, community-oriented projects in roads, bridges, electrification, marketing, and education improve the quality of rural life.

The relatively high standard of living found on small farms in the coffee-growing region of Colombia compared to that of small farms in other areas of the country, can be attributed to the organization provided by the Coffee Federation and the credit supplied by the Coffee

Bank and to a lesser extent by the *Caja Agraria*. Credit is absolutely essential in the commercialization of traditional agriculture, because technology has a price tag. In Colombia, inflationary pressures (12% annually) and inflexible credit rates force credit institutions to attempt to maximize their return by minimizing administrative costs. There is,therefore,a tendency to prefer large loans which involve large amounts of credit, without high administrative costs. Small farms are therefore at a disadvantage both because of their absolute size and their geographical distribution. Banks favor low risk activities, require security collateral, and loans are often based on the friendship and familarity of the borrower, which further accentuate the disadvantageous position of the small farmer. The availability of working capital to purchase inputs and labor is one of the most important constraints to the advancement of small farm productivity.

Coffee in the Small Farm Production System

Coffee Federation records in the Restrepo office for the period September 1974 to September 1975, showed that 63% of the local farms had less than 10 hectares (Figure 14). Although this percentage is much lower than than would be found in counties located in the more intensive coffee production departments of Antioquio and Caldas, it means that well over half of the Coffee Federation clients in the project area were small farmers. Reimundo Belalcazar Yandi is one of these farmers. His 3.9 hectare farm is located at an elevation of 1,550 meters above sea level along the Buga-Buenaventura highway near the settlement of Sabaletas. With his father and older brothers, he migrated from the



Source: FEDECAFE. 1970. *Censo Cafetero*. (Unpublished)

Figure 14. Frequency distribution of coffee farms by size (Restrepo).

department of Caldas to colonize this new region. Through their collective efforts, small fields were carved out of the forest and family unit homesteads established. Reimundo was one of the first colonists to collaborate with and receive credit through the Coffee Federation. To aid in obtaining a title to the land for use in credit applications, the Federation provided a free survey of his farm. This survey showed that 53% of the surface area was under coffee in four separate lots. Over one-half of this acreage had recently been converted from the local coffee variety (*Nacional*) to the improved variety (*Caturra*). Of the remaining farm acreage, 26% was in annual and fruit crops, 6% in pasture, 9% occupied by building and access ways, and 6% unusable because of topography.

Although electricity and drinking water have yet to be extended to the Sabaletas settlement, mechanical tools do exist. Reimundo, like every other coffee farmer in the area, has hand powered equipment to supplement the ever present hand tools (machetes, hoes, axes, etc.). These machines range from back sprayers for the application of fungicides, insecticides, and foliar fertilizaters to hand mills for removing the skin and pulp from the marketable coffee seed. Several devices exist for sun drying coffee beans after harvest. In Reimundo's case, one segment of the roof of his house was on roller skate wheels which ran along steel tracks. Coffee was placed on the top of the house and moved to one side to allow drying during daylight hours. At night or during rainstorms, the roof was moved back into place. Variations of this system were found on nearly every coffee farm, with only a small percentage of the farmers continuing to sun dry their product on uncovered concrete patios or along the paved highway.

Reimundo, now an old man, has outlived his brothers and father, thus becoming patriarch of the surviving family. Through inheritance, his total land holdings grew to 12.2 hectares, on which live five adults and four children. A large loan from the *Caja Agraria* has allowed him to purchase a Brahman bull for his two *criollo* cows and several hectares of unsurveyed grazing land on the steep mountain slopes behind his farm. However, the main income-generating enterprise continues to be the sale of coffee and plantain from his coffee plantations. Repayment of loans to improve the production resources of his farm (i.e. through the purchase of new land, fertilizers, pesticides, livestock, fencing materials, gasoline-powered coffee mills, etc.) depend on the sale of coffee.

Small Farm Lifestyle

The heterogeneity of small farms in a given region does not allow the designation of a "typical" small farm. However, from the initial 10-farm survey, personal observations, and informal contacts with farmers during the first stage of this study a few descriptive generalities can be stated. Reimundo's farm provides a good example of the physical setting and work routine of small farms around the town of Restrepo. His house, which is built on gently sloping land, is raised approximately one meter above ground level. The floor and frame of the house are constructed from purchased lumber. The walls, which are later whitewashed, are split bamboo with a mud and straw filling. The windows have wooden, painted shutters, but no glass. The house is trimmed in a bright and attractive color, and ornamamental plants are found in old cans and planter boxes on all sides. The dooryard garden also contains a wide variety of flowering plants and fruit trees.

The house is constructed so that the roof overhangs a long, narrow, wooden porch, on which sit a homemade wooden table and several wooden chairs or benches. On more prosperous farms, these chairs may be padded. The porch serves as a family room and dining area. The porch is the center of activity in a household without electricity and indoor plumbing and a place where the family, dogs, cats, chickens, and pigeons congregate. The cooking facilities, although separated from sleeping quarters in some houses, is commonly a room at one end of the house with a waist-high firepit and no chimney. The smoke finds its way out of the room through the ceiling. A considerable amount of time is spent in obtaining firewood from ever dwindling stands of virgin forest. The house may contain from one to five bedrooms depending on the number of occupants. Beds and mattresses are purchased in town. At least one room in the house is used for storage of produce, supplies, and tools.

As in most farms in the region, water is brought to the Belalcazar homestead from a small mountain stream by gravity along a split bamboo aquaduct. It cycles from a collecting tub into a wash basin and then drains down the mountain. Since cattle, wind gusts, or sudden fluctuations in water current can disrupt the plumbing, frequent maintenance of the bamboo aquaduct is necessary. Reimundo, in a gesture of affluence after consistently high world market coffee prices, replaced 150 meters of the bamboo with a heavy rubber garden hose, part of which runs underground. A visit to the Belalcazar household on any given work day, will usually find laundry in full operation, chickens running loose, and Reimundo in the field with his son and one or two laborers tending to crops.

The younger children attend a neighborhood two-room elementary school. Contrary to the low enrollment and high drop-out rates which exist in other small farm regions within Colombia and in other Latin American countries, education is highly valued in coffee growing regions. The Coffee Federation insures that each settlement and rural community in coffee regions has the essential educational facilities such as a building and desks. In addition, the Federation offers free high school through its *Concentraciones Rurales*, which combine a vocational agricultural program with conventional academic subjects. At these schools, the students spend half of each day receiving practical training in modern management techniques for field crop and livestock enterprises. Teachers are provided with special living quarters on the premises, while students are transported to and from the school on buses supplied and financed by the Federation. In order to minimize transportation costs, and to insure the adequate nutrition of the students, a subsidized breakfast and lunch program is also provided at the school cafeteria by the Federation. The students pay one peso (US $0.04) daily for a hearty breakfast and nutritional, though carbohydrate-excessive lunch.

Unfortunately, this free high school education is only available for sons and daughters of coffee farmers, who are members of the Federation, and it excludes a considerable population of landless coffee laborers, who live in town and work in all aspects of coffee production, without actually owning a coffee farm. Demonstrations, denouncements, and threats of violence against local Coffee Federation personnel by landless coffee laborers frequently occur during the registration of

new students each year. An attempt by these laborers to forceably register their children resulted in a shutdown of the *Concentracion Rural de Julio Fernandez* near Restrepo and caused considerable social tension during the first stage of this study. As in most social crises in Latin America, angry rallies were held, building walls were painted with provocative statements, and lengthy tirades proclaimed the absence of civil rights. Two months later when emotions were spent and the protests mitigated, the school quietly re-opened and life went on as before.

Community social activities in Restrepo center around the weekly market, religious services, and Coffee Federation business (meetings, loan applications, loan repayments, input purchases, etc.). Christmas is undoubtedly the social event of the year. Pre-Christmas festivities last an entire week, and local taverns extend their serviceable area by building temporary bamboo dance halls in the streets in front of their establishments. These taverns will hire professional bands from as far away as Buga, Cartago, or Cali. The consumption of *aguardiente* (sugarcane alcohol) and beer, which is high on any normal weekend, reaches staggering proportions during the Christmas festivities. Christmas in Restrepo is of the same social proportions as Mardi Gras in New Orleans.

Weekend trips to Restrepo combine socializing, the selling of farm produce, and shopping. The entire family comes into town on market day. Coffee Federation and bank personnel are required to be in their Restrepo offices until noon on Saturday to discuss loans and assist with purchases of farm inputs and building materials from the cooperative. Although one or two cows are butchered daily for a few stalls in the outdoor market plaza, from six to ten animals are butchered for the Saturday

market. Fresh vegetables, rice, potato, and clothing are also trucked in from other areas, and the market plaza becomes alive with activity. Approximately one-third of the concrete plaza is devoted to sale of unrefrigerated beef, much of it hacked off with an axe and hung from meat hooks. Another third is occupied by clothing stalls, and the final third a combination of fresh produce and food concession stands. Canned goods, bread, and other farm supplies are available from the town merchants.

The average diet in the Restrepo area is based on rice, plantain, and fried unleavened cornmeal balls (*arepas*), supplemented with meat, eggs, and beans. Perhaps the single most typical dish is *sancocho*, which is a stew made from plantain, yuca, *arracacha*, cabbage, spices, and chicken. Although *sancocho* and a few *arepas* can be a meal in themselves, they usually precede a main course of rice, fried plantain, and meat. Pork fatback with beans is also popular. A variety of fruit juices serve as beverages, but bottled soft drinks are often consumed in areas where electricity allows refrigeration. Fruits and candied fruit products are also used as desserts, but on most farms a piece of locally produced brown sugar (*panela*) suffices. Of course, coffee is the dominant beverage, served in a large cup with hot milk and sugar in the morning and as a strong, heavily sweetened refresher (*tinto*) at several points throughout the day. Hospitality dictates that any visitor to a coffee farm be served a cup of coffee. Farmers select some of the best beans from their harvest for home consumption. To further public relations, the author made a point of always commenting that of all the farms in the region that he had visited, this particular farm produced the best-tasting coffee. If the visit was lengthy, a second and third cup of

coffee would be offered. On some days, when the author visited eight to ten farms, the pupils of his eyes remained permanently dilated from overdoses of caffeine.

Unusually high world market coffee prices during the two years of this study had a notable effect on the town of Restrepo. In talking with farmers, one gets the impression that the profits and financial benefits were not getting down to their level. However farmers, by nature, are not prone to bragging to an outsider about current climatic or financial conditions. Consequently, much of their lack of enthusiasm was attributed to their belief that it was the middleman (truckers, exporters, shippers, and black market dealers) who was making the money, not the farmers themselves. The consensus was that in good years, farmers repaid the debts that they had incurred in bad years without major ameliorations in their standard of living. This premise seemed to be supported by the upsurge of activity within the Coffee Federation itself. New employment positions were created and filled, and salaries within the organization increased. There was a proliferation of new Coffee Federation-financed vehicles, and major campaigns were launched to extend coffee acreages and to improve the quality of existing acreages. This of course involved an expansion of credit to small farmers (i.e. reinvestment of coffee profits into productive resources).

However, there was also an apparent increase in the amount of money circulating in town. This can be explained as a temporary feeling of security by coffee farmers, who were then freer with their expenditures, or by the realization of substantial profits at the farm level. Whatever the reason, town commerce flourished. The first sign of this was

a significant increase in town drunkenness followed by the repainting of the church, which is the largest, most conspicuous building in town. Other notable improvements included a new prefabricated 10-room hospital, repainted farm houses and town buildings, new store signs, the addition of a new gas oven to a local bakery, and the construction of the first building in town with glass windows.

Field Crop Production

Both perennial and annual crops are found on the small farms around Restrepo. Coffee, the principal commercial crop, receives the most care and attention, and a gradient of coffee establishment and production from germination beds to old trees, far past their most productive stage, is evident on most farms. The production of annual field crops is an important component of this constant renovation of coffee acreage on small farms. However, since the rate of shaded to unshaded coffee acreage in Colombia is 100:1 (ICA, 1973), intercropping coffee stands in full production is impossible. Nevertheless, planting densities (spatial arrangement) of coffee trees and their slow establishment rate after transplanting, allow intercropping with annual crops for two or three years. These annual crops include maize, bean, yuca, and a tuber crop called *arracacha*. Plantains are also intercropped with coffee to provide shade and to diversify farm income, but Coffee Federation studies indicate that coffee quality and production can be maintained over a longer period by the use of a legume shade trade called *guamo*. This tree distributes shade, organic matter through leaf drop, and produces a saleable pod, which has a sweet pith. Coffee Federation credit is therefore easier to obtain for coffee-*guamo* plantations.

Field crops are also produced separately in monoculture or mixed intercropping systems. Although the Coffee Federation has been very successful in disseminating technological innovations for coffee production, by using them as a mandate for receiving credit, technical assistance in field crop production has been minimal. However, through its efforts at organizing farmer groups for technical assistance activities, local farmers have been exposed to technological inputs (chemical fertilizers, pesticides, and improved varieties) and the concept of crop management to maximize yields and return on investment. As a result farmers have greater confidence in technology as a tool to aid them in their struggle against the elements. The problem then, from the standpoint of improving field crop yields, is one of designing the appropriate technology.

Green Revolution thinking on the improvement of crop yields begins with the introduction of new high-yield-potential germplasm. It is interesting to note that while improved (ICA) varieties of both maize and bean are available to small farmers in Restrepo, ICA bean varieties have been more widely accepted. Farmers have not adopted hybrid maize varieties, even though the production potential of hybrids is much greater than that of local varieties. Several possible explanations come to mind. Commercial maize varieties may not have been as adaptable as commercial bean varieties to the heterogenous microclimates present in the Restrepo region. In this event, stable, though low-yielding, local varieties would provide the only reliable alternative for small farmers. Hybrid maize varieties may also have required the purchase of expensive chemical fertilizers to realize their yield potential, while commercial

bean varieties did not require additional cash inputs. With the bean market price four times greater than that of maize, bean production may be viewed as a commercial enterprise worthy of investments in technology, while maize production was subjugated to the subsistence needs of the farm family. It follows, therefore, that if technology is to be successful in increasing field crop yields on small farms, it must be agronomically adaptable and economically attractive. Since adoption rates for new technology tend to be higher with cash crops, it appears that success may hinge on the commercialization of small farm crops.

In conjunction with improved varieties, the second most effective technological resource for increasing crop yields is fertilizer. Again due to the influence of the Coffee Federation, the importance of fertilization is widely recognized in Restrepo. Credit stipulations dictate that chemical fertilizers be applied in specific doses to coffee several times per year. After many years of experience in coffee production, farmers are well aware of fertilizer composition and soil nutrient deficiencies. As would be expected, the extent of their understanding is limited, but they do use the words "phosphorus" and "micronutrient" with some degree of familiarity. However, this knowledge does not extend to other phenomena (e.g. nitrogen fixation in bean), which do not pertain to coffee production.

While chemical fertilizers are used almost exclusively in coffee production, organic fertilizer (dried chicken manure) is the most popular fertilizer used for food crop production. Occasionally a farmer will apply his surplus coffee fertilizers, particularly urea, to other crops, but this practice is coincidental with the amount on hand. A

composite analysis of the organic fertilizer (*gallinaza*) revealed a 3-4-3 formulation. However, the sample also contained calcium (8%), magnesium (0.7%), zinc (250 ppm.), and boron (17.5 ppm), whereas the most common coffee fertilizer (14-14-14) contains only macronutrients. Later soil analyses frequently indicated boron deficiencies and low levels of zinc.

In spite of the fact that farmers prefer the organic fertilizer, because of its longer-lasting slow-release effects, the price of this input more than doubled during the course of this study, due to supply-demand imbalances, inflation, and increased transportation costs. Consequently, organic fertilizers were first applied to higher value crops such as plantain, which were being planted to shade new coffee stands, while application rates for food crops decreased. In soils with widespread nutrient deficiencies this could only result in lower food crop yields. To reverse this trend suggests the need to supplement organic fertilizers with chemical fertilizers. If the supply-demand situation for bulky organic fertilizers eventually causes its price to exceed that of chemical fertilizers, farmers may gradually shift toward the more concentrated fertilizer alternatives for all crops.

Since Colombia's coffee crop has yet to be hit by any major disease or insect pest, farmer knowledge of pesticides is limited. Obvious and severe insect damage (e.g. *Spodoptera frugiperda* damage to maize) will prompt farmers to seek the advice of their neighbors or technical assistance personnel on appropriate control measures. However, the disease symptoms are often misinterpreted and attributed to temperature fluctuation and climatic abnormalities. Observations on small farm bean

production in the region revealed high incidences of disease infestation, yet warnings that pathogens are often transmitted on the seed harvested from infected pods or on residue from previous bean crops go unheeded, because farmers fail to recognize and understand the cause of the problem. Suggestions that farmers invest in preventive fungicides and apply them frequently before disease symptoms appear are even more difficult to communicate. Nevertheless, the semi-commercial (cash crop) nature of bean production in Restrepo justifies the utilization of cash inputs by most farmers. For this reason, the more progressive farmers will apply some organic fertilizer at planting and fumigate once or twice with the locally available fungicides Dithane M45 or Manzate. Occasionally a farmer will also apply the foliar fertilizers (Coljap) used on coffee trees.

Small Farm Bean Production

Since most farmers produce a few kilos of beans for household consumption, some of which may find its way into local markets, it is difficult to estimate the precise number of farms which are producing beans on a commercial scale or the total bean acreage in the Restrepo region. Existing statistical information for the region does not clarify the situation. The unpublished 1970 Coffee Federation census of the county of Restrepo, showed that only 2.4% of the total arable land area was in annual crops, compared to 30.4% in coffee and 50.2% in pasture. Someone unfamiliar with the region would assume from these data, that the large percentage of pasture land reflects a steep, mountainous topography and infertile soil conditions, which would be unsuited to field crop production. However, mountainous topography does not present a handicap

for small farm production, and soil fertility problems can be overcome. The potential arable land available for bean production is also increased by the indigenous mixed intercropping systems and by the cyclic renovation of coffee groves.

Small farms in the project region range in elevation from 1,200 to 1,600 meters above sea level. Since this altitude does not exceed the upper limit for bush bean production and is above the lower limit for climbing bean production, germplasm resources include both bean growth habits. Observations during the first stage of this study confirmed the presence of several varieties of both bush and climbing bean, however bean production was dominated by the commercial bush bean variety (ICA Calima). With a mean temperature of 20^{0} C and 1,000 mm of rain distributed over two growing seasons per year, climatic conditions are conducive to two bean crops per year. However,the more variable rainfall pattern during the second season (September to December) and possible conflicts with the principal coffee harvest of the year, suggest that bean production might be a more viable economic venture during the first season (March to June).

Two factors appear to play a significant role in determining whether a farmer will produce beans on a subsistence or commercial basis. As in all commercial activities, the first concerns the anticipated market price of beans at the end of the season compared to the profit potential of other crop enterprises. The second deals with the anticipated input and labor requirements.of coffee for the upcoming season. Both are economically rationale, because hired labor represents the single largest cash outlay in commercial production. Since labor costs are also sensitive

to the forces of supply and demand, labor is scarce and expensive at peak coffee harvest periods. Therefore, coffee production not only takes priority over other commercial enterprises for labor and cash inputs, it also indirectly affects input supply and labor costs.

Of all the food crops produced on farms in Restrepo, bush beans have the greatest commercialization potential. There is an established market for beans, their growth habit and short vegetative cycle makes them an ideal intercrop for coffee, and they can utilize labor when it is not needed in coffee production. Bean prices are also sufficiently high to warrant the use of purchased inputs. Weekly bean prices in Restrepo from October 1976 to June 1977 fluctuated from US$ 0.55/kg to US$ 0.91/kg, with a mean of US$ 0.75/kg. Maize prices for the same period averaged US$ 0.21/kg. As would be expected, the price of packaged beans in urban supermarkets was higher (US$ 0.86/kg) and somewhat more stable.

The *Instituto de Mercado Agropecuario* (IDEMA) is in charge of a price stabilization program for selected storable commodities, which includes beans, but most of their work is with rice, maize, and wheat. Since support prices are well below open market prices to encourage bulk handling of produce by the commercial sector, IDEMA is not actively involved with the small farm agricultural sector, and was not known by farmers in the Restrepo region. Conversations with Coffee Federation personnel revealed that IDEMA is hampered by lack of storage facilities and public funds with which to buy commodities. As a result, most

farmers sell directly to local merchants, who then serve as middlemen in supplying urban centers in the Cauca Valley.

The Colombian internal marketing system for food and basic consumer goods has evolved from village market days that date to the Colonial Period. Plaza type markets are found in both rural and urban centers, although supermarkets have been gaining importance in larger cities. In both centers, much of the total retail food sales are handled by small neighborhood stores and public market stall operators. Some of these neighborhood stores specialize in items such as fruit and vegetables, packaged foods and beverages, bakery products, or meat, but like convenience stores in this country, others offer a collection of items.

Credit for bean production on one hectare or more is available from the *Caja Agraria* and the *Banco Cafetero*. Credit records provide a good indication of the institutional view of return on investment in bean production in Restrepo. To cite two examples, Juan de Jesus Maldonado Mora owns a 5.5 hectare farm, which is located 12 kilometers from Restrepo in the settlement of Sabaletas. From one-half hectare of coffee, two hectares of annual crops, and three hectares of pastures, Juan estimates his annual income at US$ 430. Juan is 50 years old and has five children, who range in age from 16 to 22 years. His credit application was for US$ 285 to be repaid in seven months to plant two hectares of maize and bean. This sum is calculated to cover one-half of the labor and input costs. This means that in order to produce beans and maize commercially, Juan must have US$ 290 on hand and borrow an equivalent amount. Calculations of the lending agency forecast a potential gross

income of US$ 1,143, which would allow Juan to repay the loan and realize a net profit of US$ 567 (US$ 284/ha).

In another case, Trinidad Perdomo de Cuenca manages a 15-hectare farm 30 kilometers from Restrepo in Vijes county. His farm has one hectare of coffee intercropped with plantains, three hectares for annual cropping and 11 hectares of pasture. The annual production of his farm is valued at US$ 2,000, and the farm itself is appraised at US$ 5,714. Trinidad, who is 40 years old, has nine children, ranging in age from one to 25 years. He applied for a loan of US$ 200 to be repaid in four months in order to plant one hectare of beans in monoculture. This loan would cover 72% of the production costs. The anticipated gross income from monoculture beans was calculated at US$ 503, which after loan repayment would result in a new income of US$ 303/ha.

It is apparent that bean production is not only physically possible in the Restrepo region, it is also profitable. The institutional infrastructure has produced improved bean varieties (ICA), multiplied and distributed the seed (Cresemilla and Proacol), provided credit (*Caja Agraria* and *Banco Cafetero*), and there is some semblance of technical assistance for beans (Coffee Federation). However, in spite of the fact that all the necessary ingredients seem to be present, only a small percentage of Restrepo coffee farmers have participated in commercial bean production. This suggests that farmers lack confidence in the productivity of the existing bean production technology. If the economic benefits of bean production are to reach a larger segment of the agrarian population in the Restrepo region, serious attention must be given toward breaking the bean yield barrier. In order to improve the

productivity of traditional bean technology, it is necessary to understand the local bean production system and the limiting agronomic factors of the production environment.

Small Farm Agricultural Technology

The principal agricultural tools in traditional small farm technology are the hoe and the machete. Even though animal power is not used, mechanical power is available and a tractor-operator team can be rented by the hour in Restrepo. However, this service is beyond the economic means of most small farmers, and is used only when a pasture fallow is being converted to annual crop production. Otherwise land preparation is accomplished by hoe, and plant residues are allowed to decompose in the field. In a few instances where plant residues are excessive and decomposition is slow, such as maize stalks, residues are gathered into stacks and later burned. Outside (non-family) laborers supplement family labor during land preparation, seeding, weeding, and harvest activities.

Once the field is cleared of unwanted plants long sticks (*barretones*) are used to open holes into which several seeds are dropped. In most cases, one laborer plants the seeds and another laborer follows and covers the hole with dried chicken manure. Within-row planting distances are roughly the space of one man's stride while between-row distances vary according to the growth habit of the crop which is being established. When monoculture stands are planted, long sisal fiber strings are stretched across the field to mark rows. A furrow is then opened alongside the string with the side of a hoe and both seed and organic fertilizer are placed in the hole. This latter method was used in planting all trials in this study.

In general, plant population densities resulting from traditional planting methods are far below optimum levels. During the establishment phase of the Stage 1 experiments, farmers were instructed to plant both maize and bean monocultures as they were accustomed to planting these crops in their own fields. Measurements of planting distances were made after germination. In the nine on-farm experiments, maize was most frequently planted in rows 80 cms apart with 40 cms between plants (3 plants/m^2). A second spatial arrangement of maize was also common on small farms in the Restrepo region. This involved a quadrangular 1m x 1m spacing of holes with three maize kernels per hole (3 plants/m^2). Bush bean monocultures were planted in rows 60 cms apart with 30 cms between plants and two bean per hole (11 plants/m^2). Several studies (CIAT, 1975b; Francis et al., 1976a) have reported optimum monoculture populations of maize and bush beans to be 8 and 25 plants/m^2, respectively.

Farmers are well aware of the reduction in crop yields caused by weed competition, and weed control is usually thorough and adequate. As in other agrarian societies with a labor surplus, farmers in Restrepo spend a considerable amount of their time weeding their fields. A special weeding technique called *aporque* is used with food crops like maize and bean. It consists of concentrating both weed residues and dirt from inter-row spaces around the crop plants. Farmers contend that this hilling not only provides weed control in the immediate vicinity of the crop plant, but also adds support for the plants to prevent lodging. The author noted another possible benefit related to soil fertility. By harvesting and depositing the inter-row vegetative biomass alongside

crop seedlings, this material serves as both a mulch and as a source of soil organic matter to further crop production on low fertility soils.

In the project region maize stalks are not doubled over in the field at physiological maturity to allow drying, as is done in other bean-maize small farm zones in Latin America. Nevertheless, maize is left in the field until dry. As a result, severe bird damage was noted in maize fields on some farms. On several occasions, the author commented to farmers that doubling maize might reduce bird damage in maize monocultures and prevent accumulation of moisture within the ear during unexpected late season rains. Farmers appeared impressed with the idea and they recognized the feasibility of the concept, yet farmers did not put this technique into practice. There are several possible explanations for this response. Bird damage may be a random occurrence, affecting a relatively small percentage of maize-producing farms. Bird damage one year may not guarantee significant losses in succeeding years. Low market prices for maize may not warrant an increased investment of labor for such a low-priority, non-commercial crop. On the other hand, perhaps it is the extension method and not the technical innovation that is at fault. Verbal recommendations may not be sufficient to influence small farmer decision-making. Therefore, the extension component of this study involves a physical on-farm comparison of innovations with local technology.

The harvest, threshing, and shelling operations for field-dried maize and beans are conducted by hand, and the produce is packaged for transport and storage in burlap bags. Seed for future planting is

typically selected after harvest according to seed appearance. The moisture content of harvested maize and bean is further reduced by exposure to sunlight on the wooden trays used to dry coffee beans. Farmers generally sell a large part of the remainder of their production immediately to prevent losses due to storage insects, principally *Zabrotes subfasciatus*, and to recover financial investments. Dependence on coffee for such income means that the primary cash in-flow on small farms around Restrepo occurs twice a year. Therefore,the sale of field crop and plantain production provides much of the working capital for daily farm operation and much of the cash on hand for family-related expenses. Since the bimodal rainfall pattern permits two crops of maize or bean to be produced each year, there is little incentive to store produce for four or five months in anticipation of more favorable market prices. Some farmers will hold their produce off the market for a few weeks until prices rise slightly, but storage losses discourage this practice.

Experimental Results

The Stage 1 series of simple, unreplicated on-farm trials in themselves yielded little information, but they did legitimize the author's occasional presence in the farmer's bean fields. Without this rationale and the author's close alliance to the Coffee Federation's diversification program, the numerous questions and formal survey would have appeared somewhat suspicious. Even with these trials and the linkage with local institutions, farmers were reluctant in volunteering income related information. The selection of farms on which to place these

introductory experiments was totally at the discretion of the local Coffee Federation extension agents. In order to sample the full range of the existing farm production systems, the only stipulation placed on potential collaborators was that they have recent bean production experience or were currently producing beans.

The CIAT variety P755 (Pompadour) was selected for comparison with the commercial bush bean variety (Calima) in Stage 1 experiments on the basis of yield performance during the previous season at the *Las Guacas* research station in Popayan (1,760 meters above sea level). Although the yields for this variety were considerable lower than those of black bean varieties in the same trial, it appeared to be the most promising red bean variety then available, because of rust resistance, anthracnosis tolerance, and a similarity in color and appearance to the local variety (Calima). However, it had not been tested at the farmer level, and its productivity was found to be inferior to that of the Calima variety in Stage 1 trial (Table 7) and in the CIAT international bean trials conducted in five locations during the same season. Yield component measurements to estimate farmer maize and bean yields were made on the same farms on which Stage 1 trials were located. Calima yielded 60% more on farmers' fields than in Stage 1 trials, which suggest that Stage 1 experiments were placed on poorer quality land. Part of the yield reduction for the high lysine maize can be attributed to bird damage.

Aside from providing a basis for inquiry and communication with farmers, the Stage 1 experiments were intended to guage the importance of new germplasm in small farm production. It was hoped that the

introduction of improved varieties of bean and maize into local production systems while holding other factors constant would have an impressive effect. The results were to the contrary, while implies that these varieties require additional agrochemical inputs to attain maximum productivity. However, several other factors which deserve mention contributed to the outcome of these trials.

In an attempt to alter only the varietal factor of the farmer's production system, farmers were encouraged to plant the introduced varieties in their regular maize and bean fields at normal input levels. Two problems were immediately apparent. On one hand, many farmers already had their available annual crop land prepared and planted, and on the other hand from previous experiences, farmers expected technical assistance to come with a list of rules and regulations. In the first case, farmers sincerely wanted to be cooperative and stay in good favor with the extension agent but acreage limitations forced them to place these trials on very marginal soils, which were not comparable in quality to their own fields. Other farmers crowded the introduced varieties into their fields as border rows of varying width and plant spacing. Yet it was the second problem that was most interesting from a methodological or tactical viewpoint, because it involved a common conceptual misunderstanding between researcher and small farmer participant.

Farmers appeared quite willing to try a new practice if they were given the inputs and carefully detailed instructions and if the experiment did not require much of their productive resources. In this way, the farmer incurs little risk, and should the experiment fail, failure could be blamed on the weather, birds, or on the inadaptability of the technological innovation itself, rather than on farmer mismanagement.

Giving the farmer just the ingredients of an experiment leaves him in a very insecure position of losing face to the institutional representatives in the event of failure due to some management blunder. Therefore,while the researcher viewed the unstructured experiment as a test of fire for the technological innovation and a good means of obtaining farmer feedback, the farmers were skeptical, hesitant, and uncomfortable. As a result, farmers planted the varieties in the fashion anticipated to best please the author. In one case a farmer imitated the double row planting system used on mechanized farms in the Cauca Valley, while other farmers under the impression that organic fertilizers were incompatible with modern technology applied whatever chemical fertilizers they had on hand. No fungicides were applied, because none had been provided and no specific spraying schedule had been mentioned. There was also the possibility of applying the wrong chemical or the improper dosage. Because of the variation in planting densities and input treatments, no statistical analysis of the data in Table 7 and 8 was attempted.

To overcome these problems in the next season, it was decided that small farm land would be rented and each experimental site previewed. Instead of a flat rental fee, which would stimulate farmers to participation based on economic benefit rather than interest in expanding productivity, a gentlemen's agreement was reached with each farmer whereby he would donate his land and in turn be paid a fixed price for each kilogram of bean produced. The price was usually slightly above the red bean market value, and was paid on the basis of the weight of beans produced regardless of bean color. In this way, farmers would share in the production risk, and would thus be encouraged to prevent losses

Table 7. Data summary for bean varieties in Stage 1 trials.

Variety	Density	Pods/pl	Beans/pod	Wt/ 100 beans	Pl. ht.	Yield†
	pl/m^2			g	cm	kg/ha
Commercial	13.3	4.05	2.1	46	27.1	520.3
Promising	14.4	2.18	2.0	37	24.0	232.3
Traditional	11.1	5.11	3.0	49	38.4	833.8

† 14% moisture

Table 8. Data summary for maize varieties in Stage 1 trials.

	Density	Ear length	Kernels/ ear	Bird damage†	Wt/100 kernels	Yield§
	pl/m^2	cm		%	g	kg/ha
Com. hybrid	4.5	15.5	358.6	11.4	33	2,034
CIAT Opaque	4.0	10.5	269.6	27.5	21	920
Traditional	3.1	18.0	316.0	4.2	45	1,988

† Area of mature ear consumed by birds
§ 15% moisture

due to pests, vandals, or stray animals. CIAT would supply all necessary inputs, management and labor including hiring local labor (often the farmer himself) for weeding. More complex experimental designs and on-farm replications were therefore possible, and at the same time farmers could still enjoy status in their community as collaborators without the drawbacks of psychological insecurity.

Stage 2

Sample Size Determinations: Bush Bean

At the outset of the Stage 2 trials, certain questions concerning optimum sample size and sampling procedure were considered. Since all experimentation in this study was to be conducted on small coffee farms, where arable acreage was at a premium, minimal plot size and replications were essential. Therefore,during the harvest of one bush bean monoculture trial a study was conducted to determine optimum sample sizes.

In Figures 15 and 16,the combined coefficient of variation for nine bush bean varieties is plotted against five sample sizes for three parameters (population density, number of pods per plant, and the number of beans per pod). The differences among sample sizes for the plant density parameter were found to be highly significant (P=0.01), while sample sizes for the other parameters were not significantly different. In this and all subsequent stages of the study, plant density data for bush bean varieties were based on the number of plants in 15 meters of row. Although data for the other parameters do not show a similar decreasing sample size, the number of pods per 10 plants and the number

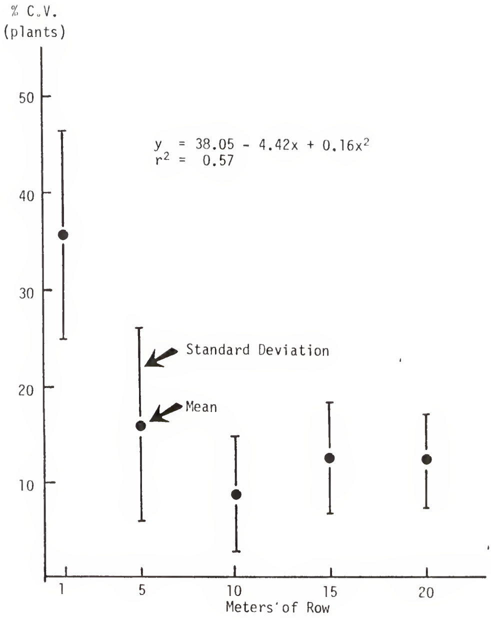


Figure 15. Effect of sample sizes on the coefficients of variation for plant density determinations in nine varieties of bush beans.

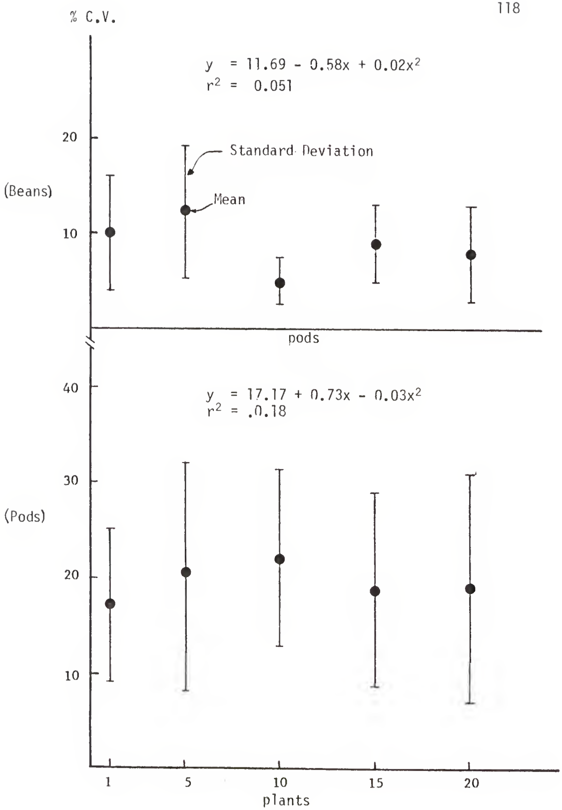


Figure 16. Effect of sample sizes on the coefficients of variation for the yield components of nine bush bean varieties.

of beans per 10 pods were selected as manageable sample sizes which had a high degree of statistical precision.

Yield Adjustments

In any comparison of several crop varieties over different locations or seasons, careful attention must be given to the relationship between yield and population density at harvest. Before any attempt was made to select varieties on the basis of relative yields in this study, regression analyses of yields per unit area on plant density at harvest were conducted. Since the yield response to increasing plant population density is normally curvilinear as optimum density levels are approached, the GLM Procedure of SAS (Barr et al., 1976) was used to fit a fixed effects linear model to the data. The equations for the model for each experimental location are shown in Table 9.

It was necessary to analyze each level of technology separately, because each was characterized by a distinct population density. However, in neither case did the population densities attain the optimum levels of 25 pl/m^2 for bush bean (CIAT, 1975b) or 12 pl/m^2 for climbing bean (Francis et al., 1976a). Therefore,no quadratic relationships were evident and none of the linear regressions showed significant yield by density interactions in spite of the high coefficient of determination (r^2) values. This can be explained by the large standard error of the estimate (Sy-x) values for each analysis, which suggest an exceptionally wide variance around the regression and an inaccurate least squares fit on the regression line.

The high r^2 values, which indicate the portion of the total variation in yield accounted for by plant density, would on the contrary sug-

Table 9. Regression statistics for yield adjustments.

Bean type	Location[†]	Mean/[††] Density pl/m^2	Mean Yield g/m^2	r^2	C.V. %	Sy-x	Yield Response Function
Traditional Technology							
Bush Mono.§	1	11.28	161.2	0.8822	17.5	48.3	$y = 151.252 - 0.02x + 0.0000002x^2$
	2	12.49	124.9	0.6325	23.3	35.3	$y = 16.595 + 0.02x + 0.00000007x^2$
Bush Inter.§	3	8.51	56.7	0.5396	45.7	28.0	$y = 66.612 - 0.01x + 0.00000005x^2$
	4	8.56	66.4	0.7629	33.3	43.6	$y = 75.325 - 0.01x + 0.00000003x^2$
Climbing Mono.¶	5	3.00	76.1	0.8559	28.9	48.4	$y = 100.244 - 0.03x + 0.0000008x^2$
Climbing Inter.¶	6	3.17	38.9	0.8036	35.9	18.5	$y = 25.974 - 0.01x + 0.0000004x^2$
Improved Technology							
Bush Mono.§	1	19.57	205.4	0.8729	15.5	64.0	$y = -48.818 + 0.03x - 0.00000007x^2$
	2	19.81	175.3	0.8763	11.0	11.3	$y = 17.438 + 0.01x - 0.00000003x^2$
Bush Inter.§	3	19.99	178.8	0.7931	17.5	49.4	$y = 355.683 - 0.02x + 0.00000005x^2$
	4	15.01	121.4	0.8855	19.1	42.1	$y = 100.481 + 0.02x + 0.00000001x^2$
Climbing Mono.¶	5	11.44	119.4	0.7725	21.8	37.9	$y = -98.196 + 0.03x - 0.0000001x^2$
Climbing Inter.¶	6	9.58	70.9	0.7715	46.6	41.1	$y = -11.011 + 0.01x - 0.00000006x^2$

† Location refers to individual farms
†† Planting densities: Traditional technology = 11.11 pl/m (bush); 3.00 pl/m (climbing)
Improved technology = 25.00 pl/m (bush); 15.00 pl/m (climbing)

¶ Six varieties
§ Nine varieties

gest that the variation in yields due to regression was greater than that attributable to random variation. However, the r^2 calculations have a slope component and are abberant when the angle of the regression line is far greater or much less than 45^0, such as occurred in these analyses (Figure 17). Null hypotheses (β=0) using t-tests were not significant for any location which confirmed that variations in plant density did not significantly contribute to the differences in yield among varieties. Therefore, no yield adjustments were necessary.

Varietal Selection

Yield potential. Of the eight field trials which were planted during Stage 2, one trial was lost completely in a flash flood and the data from another trial were disregarded because the local maize variety did not provide adequate support for the climbing bean varieties under study. The results of the remaining six trials are summarized in Table 10. The average yield of all varieties including both levels of technology over all locations was 1,363 kg/ha for bush bean and 763 kg/ha for climbing bean. Although these production levels are above the average 600 kg/ha yield level for Latin America (Francis et al., 1976a), they are far below the 4,000 to 5,000 kg/ha yields obtained under experimental conditions in Colombia (CIAT, 1975b). Highest yields in Stage 2 trials occurred in monoculture with improved technology. Under these conditions, maximum yields of 2,439 kg/ha and 1,570 kg/ha were attained for bush and climbing bean, respectively. In each of the six trials the yield of the local red bean variety was significantly lower than those of the improved varieties.

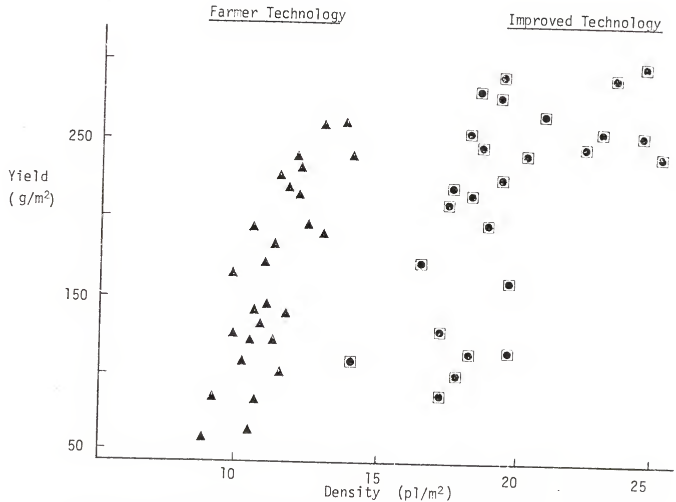


Figure 17. Yield by plant density regressions at two levels of technology for nine bush bean varieties in monoculture (location 1).

Table 10. Results from six varietal screening trials in Restrepo (Stage 2).

Variety	Bean color	Bean monoculture T_0	T_1	Bean-maize intercrop T_0	T_1	Mean
		kg/ha				
Bush bean†						
P459	Black	1807a***	2291abc***	707abc*	2073a***	1720a***
P302	Black	1589a	2439a	750ab	1663bc	1610ab
Tui	Black	1711a	2331ab	652abc	1664bc	1590ab
P524	Cream	1698a	2032bcd	836a	1476cd	1511bc
P756	White	1165bc	1744d	432c	1470cd	1203d
P643	White	1475ab	1953d	605abc	1590bc	1406c
P637	Red	979cd	1291e	528bc	1200d	1000e
P758	Brown	1674a	1964cd	582abc	1798ab	1505bc
Calima	Red	780d	1086e	452c	576e	724f
Mean		1431	1903	616	1501	1363
C.V.		20.7%	14.3%	36.9%	17.5%	19.3%
Climbing bean						
P525	Black	1176a***	1570a*	624a*	1048a*	1105a**
P259	Brown	678bcd	1431a	351b	672ab	783bc
P364	White	1021ab	1324ab	369b	832a	887b
P449	Brown	455cd	917bc	263b	800a	609c
P589	Cream	858abc	1243ab	424ab	673ab	800bc
Radical	Red	389d	682c	304b	227b	401d
Mean		763	1195	389	709	763
C.V.		28.9%	21.8%	35.9%	46.6%	31.1%

† Each of these figures is the mean from two trials

*, **, and *** denote statistical significance at the 0.10, 0.05, and 0.01 levels, respectively. Numbers in the same column followed by the same letter are not significantly different.

T_0: Farmers' Technology

T_1: Improved Technology

The utilization of improved technology increased both bush and climbing bean yields 65%. The production increase resulting from improved technology was greater in association with maize than in monoculture (Table 11). This was due to the fact that in traditional technology bean plant density is normally lower in association with maize than in bean monoculture. However, in this study, bean densities approached optimum levels in both planting systems. Bush and climbing bean yields were reduced 37% and 43%, respectively, when grown in association with maize. These data are consistent with experiment station results (Francis et al., 1977b; Francis et al., 1977c).

Bean color was found to be significantly related to yield (Table 12). Black bean production was on the average 90% greater than red bean production in bush types and 176% greater in climbing bean types. Overall, the black bean yields averaged 37% more than those of all other bean colors. Although there was some variation in performance among the three black bush bean varieties over locations and technologies, their yields were not significantly different. Consequently, the commercially available black bush bean variety (Tui) was selected to represent the high yield potential available in bush bean germplasm. Similarly, the black climbing bean variety (P525) was selected to represent the most productive climbing bean germplasm currently available. The selection of non-black varieties P524, P643, P364, and P589 was based on a combination of productivity and farmer preference.

Yield Stability. The major criticism of varieties with high yield potential is their extreme sensitivity to environments and production conditions. On the other hand, the primary assets of local varieties in

Table 11. The percentage increase in yield for two bean types in two planting systems resulting from the incorporation if improved technology.

Bean type	Bean monoculture	Bean-maize intercrop
	%	
Bush†	33	144
Climbing§	57	82

† Based on nine varieties tested in four locations
§ Based on six varieties tested in two locations

Table 12. Average bean yields in two planting systems by bean color.

Bean color	Bean monoculture	Bean-maize intercrop	Mean
	kg/ha		
Bush†			
Black	2028	1252	1640
Red	1034	689	862
Other	1713	1099	1406
Climbing§			
Black	1373	836	1105
Red	536	266	401
Other	991	548	770

† Tested at four locations
§ Tested at two locations

traditional agriculture is their yield stability. If improved varieties are to have a wider range of adaptation, involve less production risk, and be accepted by low income farmers, yield stability characteristics must be considered on an equal basis with productivity. Eberhart and Russell (1966) proposed a method by which analysis involves a linear regression of the yield of each variety by which analysis involves a linear regression of the yield of each variety on the mean yield of all varieties for each site. The latter provides a quantitative stratification of the environments from less favorable to highly favorable for crop production. Therefore, the environmental index functions as the independent variable, and the selection criteria for a high-yielding stable variety would include above average productivity and a slope approximately that of the average of all varieties over all locations (β=1.0).

The regression lines showing the relationship of the yield of the selected bush and climbing bean varieties and the local red bean varieties over a range of environments are presented in Figures 18 and 19. Because of the limited number of locations involved in these experiments, each level of technology and planting system was treated as a separate environment. The yield stability of these varieties is reflected in their respective slope (β) values. It is interesting to note the similarity in behavior of the local red bean varieties of both bean types. Above average yields were obtained under less favorable environmental conditions, such as those found on small farms where water and pest control were inadequate and soil fertility limiting, but there was no yield response to more favorable conditions. This suggests that these varieties were selected for unfavorable conditions. Since technological

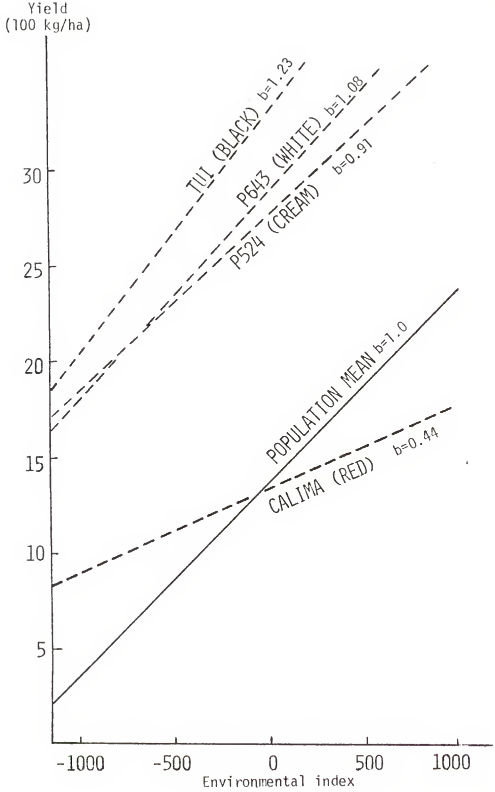


Figure 18. The response of four bush bean varieties to various environments.

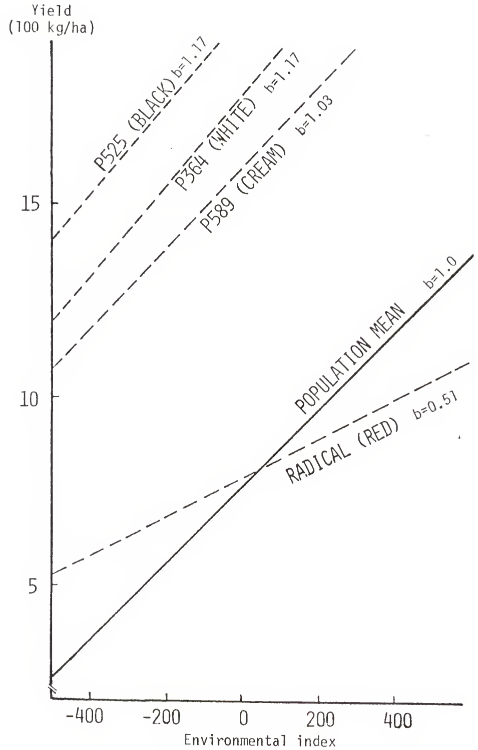


Figure 19. The response of four climbing bean varieties to various environments.

innovations (e.g. fertilizers, pesticides, irrigation equipment, etc.) facilitate production by creating conditions more conducive to plant growth and development, it follows that these varieties were selected for traditional, low input technology and do not therefore readily respond to improved technology.

To further explore this line of thinking, a method proposed by Finlay and Wilkinson (1963) was used to interpret varietal adaptation. This procedure is similar to the Eberhart and Russell regression but also involves plotting the regression coefficients for each variety against the mean variety yield expressed on a logarithmic scale for each location (Figures 20 and 21). Varieties whose regression coefficients lie in the upper right corner of the graph closest to the line (r=1) are high-yielding and well-adapted to all environmental conditions. The position of the regression coefficients for the local red bean varieties, Calima and Radical, indicates that these varieties are specifically adapted to unfavorable environments. If farmers or researchers are attempting to select varieties for the existing level of small farm technology and if these varieties are to be released without additional input recommendations, then this selection criterion is valid. The widespread use of the commercial variety (Calima) among small farmers throughout the country would tend to support this methodology. However it is the contention of this author that improved varieties are but one of many potential technological innovations by which to increase small farm productivity. If significant yield increases are to be attained to permit some commercialization of traditional agriculture, a composite technology must be designed. Therefore varietal selection

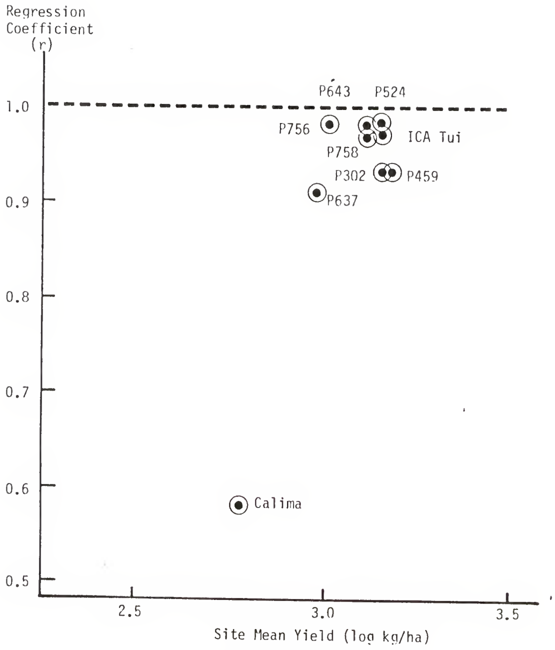


Figure 20. The relationship of varietal adaptation (regression coefficient) and variety mean yield for nine varieties of bush bean.

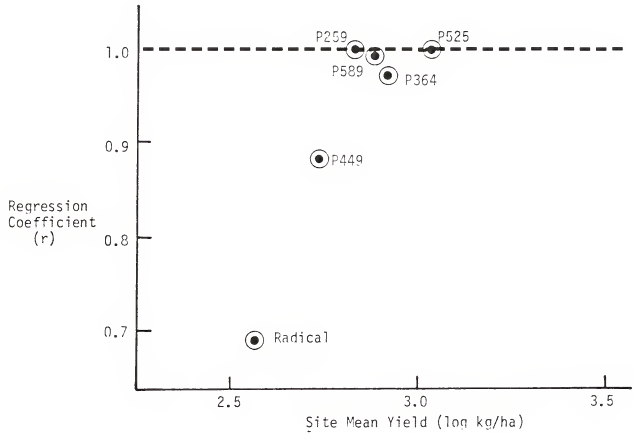


Figure 21. The relationship of varietal adaptation (regression coefficient) and variety mean yield for six varieties of climbing bean.

must consider yield potential over a range of environmental conditions and yield response to improved technology. This approach would assure wide adaptability, and at the same time allow the tailoring of complementary technological inputs according to subregional specifications and limiting factors (i.e. a technological package).

Statistical Interactions

Since intercropping systems dominate small farm production, local varieties have been selected over many years for survival and yield stability in intercropping. However, varietal improvement emphasizes high-input monoculture systems. Research in bean production has focused on the more determinate bean types, which are better adapted to mechanized farming. The question arises, will varieties which were selected under monoculture conditions using a high level of technology perform equally well in intercropping systems at the farmers' level of technology? Since experiment stations are commonly located on fertile valley soils, where microclimatic conditions are much more favorable to crop production than those on small farms, another question presents itself. In the design of improved small farm technology, should varietal screening take place under production conditions (i.e. in small farmers' fields)? The answers to these questions lie in the significance of genotype by system, genotype by technology, genotype by location, and genotype by season interactions.

Table 13 shows that there is a highly significant correlation in both rank order and variety yields between monoculture and intercropping planting systems. A similar relationship exists between varieties planted at two levels of technology in bean monoculture (Table 14). Although the

Table 13. Correlation coefficients for the rank order and yield of bush and climbing bean varieties in monoculture and intercrop planting systems.

Correlation	Bush	Climbing
Spearman Rank	0.92**	0.83**
Yield	0.94**	0.88**

** Significant at the 0.01 level

Table 14. Correlation coefficients for the rank order and yield of bush and climbing bean varieties at two levels of technology.

	Bush bean		Climbing bean	
Correlation	Monoculture	Intercrop	Monoculture	Intercrop
Spearman Rank	0.82**	0.53NS	0.83**	0.54NS
Yield	0.92**	0.54NS	0.86**	0.61NS

NS and ** denote Not Significant and Significant at the 0.01 level, respectively.

same relationship was not significant in association with maize, this may have been due to the fact that bean yields were suppressed due to competition from maize plants so that the absolute differences among varieties were not as great. More specific Spearman Rank Correlations were conducted to further explore genotype by technology interactions (Table 15).

Even though the differences between individual bush and climbing bean varieties and the two levels of technology were significant over all locations, the genotype by technology interaction was only significant in the bush bean-maize intercrop (Tables 16 and 17). Apparently competition with maize plants resulted in significant differences in seed size between the technology level treatments. This is also reflected in the highly significant technology by location interaction for the bush bean association. It is important to note that there was a highly significant genotype by location interaction in both monoculture and intercropping systems, suggesting that these factors are not independent of each other.

From these analyses, it is evident that varieties selected in monoculture at a high level of technology are also productive in other planting systems or at lower levels of technology. Other authors (Francis et al., 1976a; Francis et al., 1977b) have reported non-significant genotype by system interactions with both bush bean and climbing bean varieties, however there appears to be some genotype by system interaction in maize (Francis et al., 1976a) and a highly significant genotype by season interaction (Francis et al., 1977b).

Table 15. Spearman Rank Order correlation coefficients for bush and climbing bean varieties in two converse comparisons.

Comparison	Bush	Climbing
Monoculture, improved technology vs intercropping, farmers' technology	0.82*	0.71*
Monoculture, farmers' technology vs intercropping, improved technology	0.87**	0.83**

*, ** Significant at the 0.05 and 0.01 levels, respectively

Table 16. Levels of significance for the influence of variety, technology, and their interaction on yield and the components of yield.

	Bush bean monoculture		Bush bean-maize intercrop		Climbing-maize intercrop	
	Loc. 1	Loc. 2	Loc. 3	Loc. 4	Loc. 5	Loc. 6
Yield						
Tech. (T)	**	**	**	**	**	**
Var. (V)	**	**	*	**	**	*
T x V	NS	NS	**	*	NS	NS
C.V.	17.9%	15.6%	23.3%	22.7%	23.9%	43.6%
Plant height						
Tech. (T)	**	**	**	NS	NS	*
Var. (V)	**	**	**	**	**	**
T x V	NS	NS	NS	NS	NS	NS
C.V.	17.0%	23.8%	16.1%	16.6%	26.0%	15.0%
Pods/plant						
Tech. (T)	**	**	**	NS	NS	*
Var. (V)	**	**	**	**	NS	**
Tx V	NS	NS	NS	NS	NS	NS
C.V.	22.6%	29.9%	30.6%	36.7%	40.4%	38.0%
Beans/pod						
Tech. (T)	NS	*	NS	NS	NS	NS
Var. (V)	**	**	**	**	**	**
T x V	NS	NS	NS	NS	NS	NS
C.V.	8.6%	6.8%	13.8%	11.3%	7.2%	9.3%
Wt. 100 beans						
Tech. (T)	NS	NS	*	*	NS	**
Var. (V)	**	**	**	**	**	**
T x V	NS	NS	NS	NS	NS	NS
C.V.	11.8%	6.2%	9.5%	8.0%	9.1%	8.1%

NS, *, ** denote Not Significant and Significant at the 0.05 and 0.1 levels, respectively.

Table 17. Levels of significance for location, variety, technology, and their interaction on bush bean yield in two systems.

	df	F values	
		Monoculture	Bean-maize intercrop
Location (L)	1	58.99**	0.03NS
Variety (V)	8	19.24**	7.40**
Technology (T)	1	1.79NS	25.29**
L x T	1	1.44NS	14.04**
L X V	8	3.27**	3.07**
T x V	8	1.88NS	5.99**
L x T x V	8	1.18NS	1.82NS
C.V.		16.57%	23.38%

NS and ** denote Not Significant and Significant at the 0.01 level, respectively

Initial Farmer Participation

Three types of extension activities were used to impress upon farmers the value of improved varieties and to expose them to the bean research program under way in Restrepo. These included a field day tour of Stage 2 trials prior to harvest, followed several weeks later by a formal presentation of the research results, and the introduction of several promising varieties of maize, beans, and yuca. The field day exemplified the close collaboration of research, extension, and private sector entities in this study. The Coffee Federation organized and provided transportation for 45 farming group leaders and extension personnel for the one day event. The ABOCOL fertilizer company supplied a lunch of stuffed pork and beer, and several technical specialists from CIAT attended to observe CIAT varieties in small farm production and to answer farmers' questions.

The field day was conducted after flowering, but before full physiological maturation of the developing pods. In this way, the farmers were not tempted to remove pods off the most impressive plants for their own experimentation. Public officials from Restrepo were also in attendance so that no recognized local authority was excluded from the program. News media representatives covered the event, and articles with photographs appeared later in all three major newspapers in Cali (*Occidente*, *El Pueblo*, and *El Pais*). The publicity was actively encouraged by ABOCOL as a promotion for their fertilizers and investments in Colombian agricultural productivity. From the standpoint of establishing an identity in the community, the field day was a tremendous success and the author's subsequent activities in the region were no longer suspect.

Once sampling and data analysis were complete, another farmer meeting was organized. The same farmers who had attended the field day gathered at the Coffee Federation school (*Concentracion Rural de Julio Fernandez*) in Restrepo for the presentation of research results. In order to make the presentation more meaningful and intelligible to small farmers, yield measurements were expressed in terms of production per unit weight of seed used. Small farmers seldom plant a complete hectare of any given crop in monoculture and intercropping systems make conversions to a monoculture production per hectare basis difficult. Since most small farms have not been surveyed, farmers do not know the precise dimensions of their bean fields. However, farmers are usually conscious of the amount of seed of a particular crop that is planted. By expressing production on the basis of kg/kg seeded, farmers could more clearly visualize the production potential of these new varieties in terms transferrable to their individual farms.

Net income calculations (Table 18) also exposed farmers to the profit potential inherent in the use of improved technology and new bean varieties. These economic returns were estimated on the basis of variable or input costs and did not consider fixed costs. Since there was insufficient information on the specific labor requirements for each aspect of bean production in Restrepo, labor costs were generalized and were not considerably greater in the improved technology treatment. Gross income was approximated using a market price scale favoring red bean (US$ 0.75/kg) over other bean colors (US$ 0.49/kg). Variable costs were 18% (US$ 37.22/ha) greater under improved than under farmer technology, however the bean production increase due to technology more than

Table 18. Net income for the varieties selected in Stage 2 trials compared to that obtained using local bean varieties.

Variety	Color	Monoculture		Intercrop	
		Farmer technology	Improved technology	Farmer technology	Improved technology
		US$/ha			
Bush†					
Tui	Black	503.71	724.91	230.89	615.82
P524	Cream	498.08	600.39	307.65	537.60
P643	White	405.06	567.23	211.49	584.95
Calima	Red	235.41	373.04	217.41	250.76
Mean§		416.92	587.38	232.78	592.49
Climbing					
P525	Black	280.54	407.67	219.42	359.07
P364	White	215.88	305.05	113.05	268.96
P589	Cream	147.89	271.27	135.99	202.64
Radical	Red	67.84	239.90	176.27	84.04
Mean¶		127.46	284.81	136.52	228.76

† Each number represents the mean for two trials
§ Mean for nine bush bean varieties
¶ Mean for six climbing bean varieties

compensated for the additional expense. The value of maize (US$ 0.20/kg) did not adequately offset the lower bean yields obtained in the maize-bean intercrop. This was particularly evident at the farmers' level of technology. It is interesting to note that the Radical, which was selected in maize intercrops at farmer technology, had a high net return for this system.

Inquiries into the experimental outcome of the maize, bean and yuca varieties given to farmers revealed that farmers were interested in trying new varieties. The white bush (P643) and climbing (P364) varieties were most popular because a white bean variety (*Blanquillo*) is produced in the Pasto region of Colombia and sold in the Valle Department. Yields of the commercial maize hybrid (H302) were superior to those of other maize varieties. Although the black varieties also had high yields, farmers were unaccustomed to black beans, refused to eat them, and found that they had a very low market value. At the termination of Stage 2 experiments, an official report was submitted to the Coffee Federation to accompany an earlier project proposal.

Stage 3

Bean Color

The high yield potential of black bean varieties had been recognized in Colombia prior to this study. Table 19 shows the production, area, and yield differences between red and black bean varieties in Colombia. The black bean varieties are most commonly grown under mechanized conditions on large farms for export, while the red bean varieties are raised on small- and medium-sized farms for domestic consumption.

Table 19. A comparison of red bean and black bean production in Colombia.

Factor	Year 1970	1971	1972	1973	1974	1975	1976
Production	1000 metric tons						
Red bean	38.8	35.6	42.0	47.8	51.5	62.4	61.4
Black bean	8.0	12.9	18.2	9.1	15.6	27.5	3.5
Area	1000 ha						
Red bean	66.4	60.0	68.8	78.8	80.0	96.0	90.6
Black bean	4.5	8.8	15.8	8.5	10.7	24.7	2.8
Yield	kg/ha						
Red bean	584	593	624	609	644	650	678
Black bean	1778	1466	1152	1702	1458	1113	1250

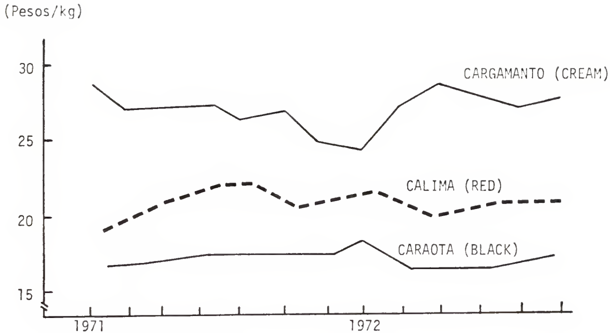
Source: OPSA. 1976. *Cifras del Sector Agropecuario. Ministerio de Agricultura.* Bogota, Colombia.

Colombians find black beans unappetizing, both in themselves and because they discolor other foods on the plate. This dislike is reflected in bean prices (Figure 22). In the Restrepo vicinity, the red bean variety Calima is preferred over all other varieties. Since none of the varieties selected in the Stage 2 trials were red-seeded, additional variety screening trials in search of high-yielding red bean varieties were necessary in Stage 3.

Table 20 demonstrates that very high yields up to 2,665 kg/ha for bush bean and 2,435 kg/ha for climbing can be obtained on small farms. Abnormally low rainfall during the post-flowering period was apparently conducive to high bean yields in the trials. The plant density by genotype interaction was not significant, but there were significant differences among the yield components of the varieties under study (Table 21). The CIAT red bush bean varieties showed no statistically significant increase in yields over the local variety (Calima), however two red climbing bean varieties gave significantly higher yields than Radical. Unfortunately, commercial bean production in Restrepo is based on bush bean varieties. The author was therefore confronted with the decision of which bean color to use in the preliminary technological package in Stage 4.

Sample Size Determination: Climbing Bean

In order to supplement the sample size information on bush bean gathered in Stage 2, a similar study was conducted in a nine variety climbing bean trial to determine the optimum sample sizes for estimating population density, number of pods per plant, and the number of beans



Source: Orozco, 1973.

Figure 22. Commercial bean prices: *Departamento del Valle* (June 1971 - June 1972).

Table 20. Yields of promising red bean varieties in Stage 3 trials.

Variety	Color	Location 1		Location 2		Mean	
		Yield†	Rank	Yield†	Rank	Yield†	Rank
		kg/ha		kg/ha		kg/ha	
Bush bean							
Line 20738	Red	1985ab	8	1053ab	11	1519abc	10
P221	Red	1901abc	10	1242ab	7	1572abc	9
P458 (Tui)	Black	2323ab	3	1167ab	8	1745ab	4
P130	Red	2096ab	5	1124ab	9	1610abc	8
P45	Red	904d	14	850b	14	877d	14
P643	White	2662a	2	1322ab	3	1992a	1
P132	Red	2063ab	7	1270ab	4	1667ab	6
P124§	Red	2131ab	4	1453a	1	1792a	3
P524	Cream	1980ab	9	1247ab	6	1614abc	7
P169	Red	1167cd	13	902ab	12	1035cd	13
P87	Red	1497bcd	12	853b	13	1175bcd	12
P692 (Calima)	Red	2066ab	6	1421ab	2	1744ab	5
P366§	Red	2665a	1	1259ab	5	1962a	2
P141	Red	1863abc	11	1072ab	10	1467abc	11
Mean		1950		1160		1550	
C.V.		16.4%		28.9%		20.8%	
Climbing bean							
P525	Black	1950mn	6	2028mn	4	1989m	4
P103§	Red	2168mn	3	2435m	1	2302m	2
P364	White	2264m	2	1540mn	6	1902mn	5
P82	Red	899op	8	977mn	9	938o	9
P589	Cream	2118mn	4	2019mn	5	2068m	3
S118	Red	2098mn	5	1460mn	7	1779mno	7
Radical	Red	742p	9	1370n	8	1056no	8
S220§	Red	2337m	1	2422m	2	2379m	1
P50	Red	1506no	7	2133mn	3	1819mno	6
Mean		1787		1820		1804	
C.V.		15.2%		39.5%		29.5%	

† Numbers in same column followed by same letter are not significant at 0.01 level.
§ Varieties selected for the preliminary technological package to be evaluated in the fourth stage.

Table 21. F values and levels of significance for yield components in the Red Bean Variety Trials (Stage 3).

Component	Bush bean		Climbing bean	
	Loc. 1	Loc. 2	Loc. 3	Loc. 4
Density				
Den. x Var.	0.77NS	0.71NS	1.10NS	1.30NS
C.V.	17.47%	31.45%	14.82%	36.59%
Pl. ht.				
Var.	8.17**	0.87NS	7.78**	6.04**
C.V.	8.24%	18.68%	17.45%	23.89%
Pods/pl.				
Var.	9.80**	7.21**	5.30**	1.73NS
C.V.	22.46%	26.03%	26.59%	36.11%
Beans/pod				
Var.	12.16**	13.22**	54.97**	31.73**
C.V.	9.08%	9.60%	5.81%	7.23%
Wt. 100 beans				
Var.	47.72**	215.55**	142.89**	54.12**
C.V.	8.58%	4.27%	5.50%	9.30%

NS and ** denote Not Significant and Significant at the 0.01 level, respectively.

per pod (Figure 23). There were no significant differences among sample sizes for the three parameters. Consequently, population density measurements were taken on 12 meters of row, while the number of pods per 10 plants, and the number of beans per 10 pods were used to estimate the other yield components.

Limiting Factor Trials

The results of the on-farm trials, which involved bush and climbing bean in two planting systems, to establish a priority ranking of the agronomic bean production factors are shown in Table 22. If bean yields are to be maximized, soil fertility, disease control, and planting density demand special attention. Diseases caused a greater yield reduction in bush bean than in climbing bean (Table 23). Most of the pathogens were fungi including Angular Leaf Spot (*Isariopsis griseola*), Rust (*Uromyces phaseoli*), and Anthracnos (*Colletrotrichum lindemuthianum*), but Bacterial Blight pathogens (*Xanthomonas phaseoli*) and Commun Mosaic Virus were also frequently present. Many of the diseases were seed transmitted, and infestations were particularly acute where undecomposed residues of a previous bean crop remained on the soil surface.

Clean seed (i.e. seed produced from disease free plants) was not available and seed treatment with fungicides was found to be ineffective (Mike Ellis, CIAT, 1976, Personal Communication). Seed-transmitted diseases reduce germination and seedling losses in bean, which may explain the 32-50% decrease in plant population from establishment to harvest reported in an earlier survey of 177 Colombian farms (CIAT, 1975b). Foliar applications of the wide spectrum fungicide Dithane M45

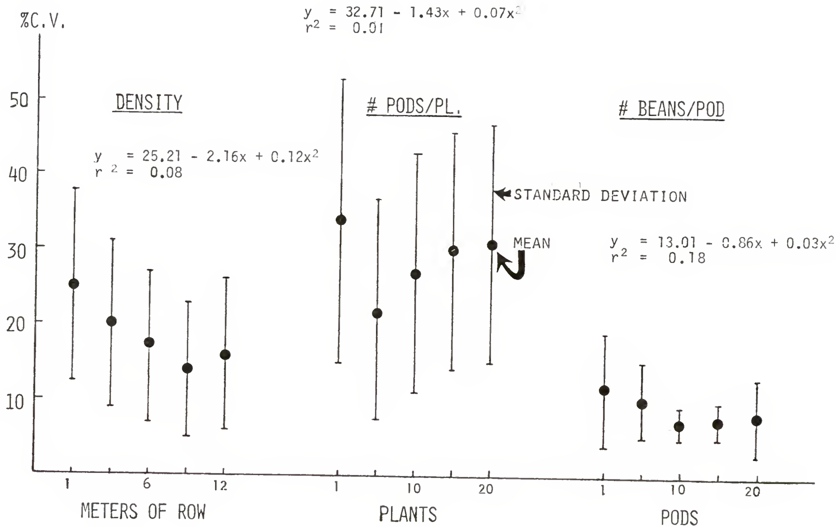


Figure 23. Effect of sample sizes on the coefficients of variation for the yield components of nine climbing bean varieties.

Table 22. Results of the Limiting Factor Trials (Stage 3).

Treatment	Location 1				Location 2			
	Bush		Climbing		Bush		Climbing	
	Mono.	Inter.	Mono.	Inter.	Mono.	Inter.	Mono.	Inter.
	kg/ha							
Complete (C)	1716ab	1133a	1459ab	429ab	1079a	1043a	1007a	1021a
C - Variety	1743ab	1110a	1304b	518a	1052a	1227a	767ab	811a
C - Density	1084bc	694b	842b	391ab	865b	738ab	539bc	534ab
C - Fertilizer	942bc	595b	1176b	349ab	318b	550b	391bc	490ab
C - Insect cont.	1978a	1134a	1932a	745a	1501a	868ab	725ab	1051a
C - Disease cont.	859c	534b	1073b	363ab	436b	491b	748ab	779a
Farmer tech.	1513bc	776ab	155c	74b	1016a	711ab	177c	128b

Numbers in the same column followed by the same letter are not significantly different at the 0.05 level.

Table 23. Reduction in yield as a percentage of the control (complete technology) treatment.†

Treatment	Bush			Climbing		
	Mono.	Inter.	Mean	Mono.	Inter.	Mean
	--------------------------		%	--------------------------		
C - Variety	1.0	7.4	4.2	-16.0	- 8.3	-12.2
C - Density	-30.3	-34.2	-32.3	-39.9	-36.2	-38.1
C - Fertilizer	-54.9	-47.4	-51.2	-36.4	-42.1	-39.3
C - Insect control	24.5	8.0	8.3	7.7	23.9	15.8
C - Disease control	-53.7	-52.9	-53.3	-26.2	-21.2	-23.7

† Each number represents the mean from two trials

were used as a preventative treatment for fungal diseases throughout this study. In addition the copper (Cu) based fungicide Koccide, was applied because of its ability to control bacterial blight (Weller and Saettler, 1976).

The major element limiting soil fertility in the Restrepo region is phosphorus (P). Soil acidity is very high on many farms, with pH levels of 5.5 or below (Appendix D). Liming the soil to increase phosphorus availability and organic matter decomposition is not recommendable because of negative effects on micronutrient availability and soil structure. Therefore,in spite of high phosphorus fixation rates, applied phosphorus is the only feasible means of overcoming phosphorus deficiencies. Many sources of phosphorus are available in Colombia, and application rates are studied in Stage 4.

Boron (B) and zinc (Zn) deficiencies are much more difficult to control, because of the fine line between micronutrient deficiency and toxicity. The major Colombian micronutrient fertilizer for soil application has the brand name *Agrimins*. This fertilizer, which bears an ICA registration number, is a 9-5-8 formulation with 14% calcium (Ca), 0.9% B, 0.4% Zn, and seven other micronutrients. Applications of sufficient quantities to correct one micronutrient deficiency may in turn result in toxicity levels of another micronutrient. Fortunately, imported foliar fertilizers (*Coljap* and *Bayfolar*) used in coffee production are also available. *Bayfolar* is a 11-8-6 formulation with 0.0113% B and 0.006% Zn in addition to iron (Fe), copper (Cu, cobalt (Co), manganese (Mn), and molybdenum (Mo). Although relatively expensive, the proper use of these foliar fertilizers can prevent plant nutrient

deficiencies. For experimental purposes, the chemicals $ZnSO_4$ and Solubor were used in this study to eliminate interactions with other micronutrients.

In general, insect damage in the post-seedling stages did not reduce bean yields in the project area. However, soil dwelling grubs, particularly *Gryllus* spp. and *Prodenia ornithogalli*, did thin out seedling stands immediately after germination, forcing reseeding or heavier seeding rates, but this was a short term problem. Other insects (*Diabrotica* spp., *Tetranychus desertorum*, *Empoasca kraemeri*, and *Liriomyza* spp.) were noted in both experimental plots and farmer fields, but severe insect damage was uncommon and very localized. In the limiting factor trials, higher yields were obtained when Furadan was not applied at planting. Sparse rainfall during the establishment period and throughout this season resulted in moisture stress following germination. Seedling development was further stunted when roots came into contact with Furadan. Therefore, since insect control was not necessary, Furadan had a deleterious rather than an advantageous effect on plant growth.

When the yields of red bean and black bean varieties are contrasted over Stage 2 and Stage 3 trials, a genotype by season interaction is evident. Rainfall during Stage 3 experimentation was light and poorly distributed. Farmers reported that late planted bean and most maize crops failed due to moisture stress. This exemplifies the risk factor of rain-fed agriculture. Farmers, who planted after the very first rains, experienced red bean yields far above normal, while farmers who planted one or two weeks later failed to recover the seed they planted. Table 24 shows that the variation in rainfall, which is synonymous with

Table 24. Rainfall data (1972-1976) showing the variation in the bimodal rainfall pattern (Restrepo, *Valle de Cauca*, Colombia).

Month	Year 1972	1973	1974	1975	1976	Mean	Variance†	
	mm							
January	47	8	25	14	32	25	236	
February	38	9	118	76	69	62	1692	
March	76	106	49	113	84	86	650	First Season
April	134	100	132	59	119	109	959	First Season
May	99	71	138	119	115	108	630	First Season
June	84	119	60	104	62	86	667	First Season
July	52	76	45	76	6	51	828	
August	56	87	42	111	19	63	1327	
September	72	154	125	83	15	90	2830	Second Season
October	143	194	168	154	139	160	496	Second Season
November	102	149	115	135	63	113	1101	Second Season
December	71	64	29	102	66	66	673	Second Season
Total	974	1131	1046	1146	789	1017		

† Total variance by growing season: March - June = 2906
Sept. - Dec. = 5100

Variance for the first two critical months of each season:
March and April = 1609
Sept. and Oct. = 3326

Source: CENICAFE. 1973-1977. *Precipitacion en la zona cafetera.* Vols. 26, 38, and 50. *Federacion Nacional de Cafeteros Colombianos.* Chinchina, Colombia.

risk, is greater in the second season (September to December). Research (CIAT, 1976b) has shown a differential response among bean varieties to drought and flooded soil conditions. There is some indication that black seeded varieties withstand flooded conditions better than varieties with other seed colors, while red bean varieties are more drought tolerant. This may be related to the respective areas of origin of the different varieties, or it may simply be due to disease resistance, since disease incidence is greater under high humidity conditions.

Some difficulty was encountered in establishing a normally competitive maize associate crop in the Location 2 trial. Local birds devoured the maize seed and uprooted maize seedlings which forced several reseedings. The resulting stand of maize was not uniform and was not in optimum synchronism with the bean intercrop. This explains the yield similarity between the two planting systems of both bean types at Location 2.

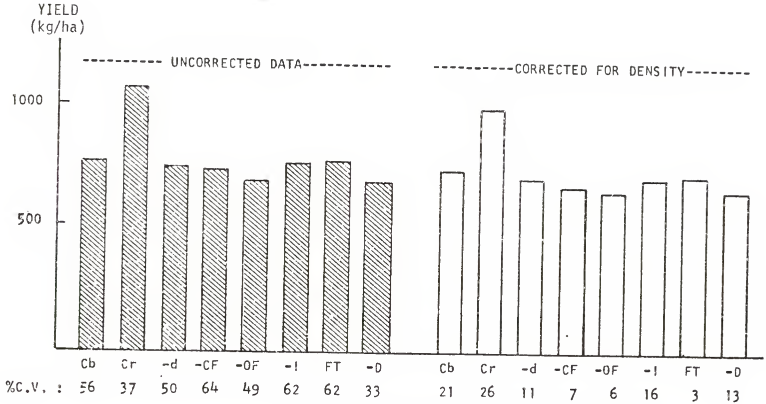
Farmer Group Trials

The second type of limiting factor experiments consisted of 16 trials, each conducted with a separate farming group. The dispersion of these groups, each of which served as a replication of the overall regional experiment, was previously illustrated in Figure 4. Although seed and planting materials were prepared at the beginning of the season for 20 farming group trials, only 16 were planted. Of these, 11 were harvested. Most of the unharvested trials were lost because of late planting, livestock grazing or trampling experiment plots, or because some farmers harvested the plots and mixed the individual treatments in the process of drying and threshing.

The yields of the individual treatments with nine replications are presented in Figure 24. There were no significant differences among treatments. Apparently the differences among farms, which is reflected in the high coefficients of variation for replications of individual treatments, was greater than that among treatments. Differences of microclimate and soil conditions among farms undoubtedly account for some of this variation, but most of it can be attributed to different planting dates and input application schedules. In an attempt to reduce the coefficient of variation for replications, treatment yields were adjusted to population density at harvest using simple linear regression. Nevertheless, the differences among adjusted treatment yields were still not significant. Even though from a research standpoint these farmer group trials were not conclusive, they stimulated a great deal of interest in the study and demonstrated the relative importance of agronomic cultural practices in bean production on a local level.

Requirements for Maximum Bean Productivity

Since water control and soil fertility are critical factors in bean production, the yields obtained under the carefully controlled conditions at CIAT can be considered optimum for maximum bean yield. When the red bush bean variety, Calima, is subjected to the rigors of the small farm production environment in Restrepo yields are reduced by approximately 50% (Figure 25). There is a further reduction of about 30% when Calima is produced under the traditional level of technology. Therefore, fertilizer and pest control technology in Restrepo can only increase Calima yields about 30% over what farmers currently experience. Although the yield variation between replicated and farmer group trials



Cb: COMPLETE TECHNOLOGY (BLACK BEAN VARIETY)
Cr: COMPLETE TECHNOLOGY (RED BEAN VARIETY)
-d: COMPLETE TECHNOLOGY - DENSITY
-CF: COMPLETE TECHNOLOGY - CHEMICAL FERTILIZER
-OF: COMPLETE TECHNOLOGY - ORGANIC FERTILIZER
-I: COMPLETE TECHNOLOGY - INSECT CONTROL
FT: FARMER TECHNOLOGY
-D: COMPLETE TECHNOLOGY - DISEASE CONTROL

Figure 24. Results of nine Farmer Group Trials to identify and quantify the agronomic factors limiting bean production (Stage 3).

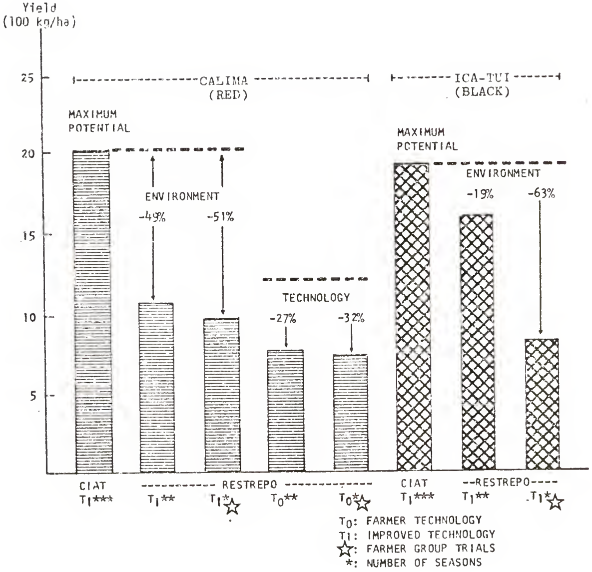


Figure 25. Yield comparison of red and black bush bean varieties over locations and technology levels.

with the black bean variety Tui was greater than that of Calima, the average yield reduction due to environmental factors was not as severe. This suggests that maximum bean yields in Restrepo will require an improved variety (less environmental sensitivity), fertilizer and disease control technology, and water control.

Stage 4

Phosphorus Level Trials

Table 25 summarizes the agronomic yield response of both bush and climbing bean varieties to increasing levels of phosphorus fertilization. Significantly higher yields were obtained at higher rates of application (Figure 26). Bush bean varieties showed an overall linear yield response up to 150 kg P_2O_5/ha, while the climbing bean yield plateau began at 100 kg P_2O_5/ha. Individual variety yields (Figures 27 and 28) confirm the "minimum" 50 kg P_2O_5/ha application rate used in the improved technology treatment earlier in the study. However, cost and return analyses (Figure 29 and 30) suggest that "optimum" economic benefits can be realized at application rates in the vicinity of 100 kg P_2O_5/ha. The genotype by fertilization level interaction was not significant for either bean type.

Farmer Group Trials

The multilocation testing of the preliminary technological package was accomplished on 12 farms (i.e. 12 replications). Four of these trials were lost and results from a fifth trial were disregarded because the farmer applied additional nitrogen (urea) to some plots. The success

Table 25. Bean yields at four levels of phosphorus (Stage 4).†

Variety	Color	Kg P_2O_5/ha 50	100	150	200
		---------------kg/ha---------------			
Bush					
P366	Red	1201b	1452ab	1747a	1815a
P124	Red	1146y	1448xy	1491xy	1751x
Calima	Red	1106e	1300de	1512d	1651d
P458	Black	1332j	1469j	1499j	1536j
P643	White	1143s	1415rs	1564r	1703r
Climbing					
P103	Red	1248a	1092a	1559a	1406a
S220	Red	1179y	1871x	1588xy	1800x
P525	Black	1548d	2014d	1905d	1916d
P364	White	2022j	2056j	1889j	2291j

† Each number is mean of two trials
Numbers in the same line followed by the same letter are not significant at the 0.05 level.

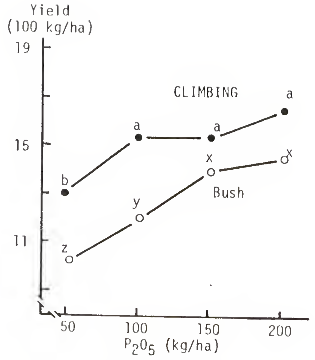


Figure 26. Average response of all bean colors to applied phosphorus.

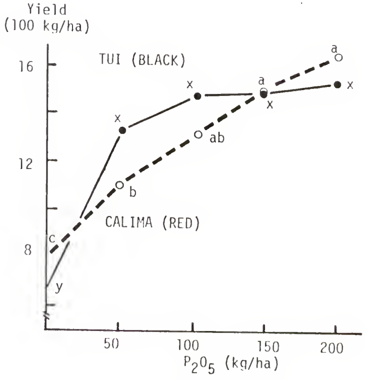


Figure 27. Yield response of two bush bean varieties to applied phosphorus.

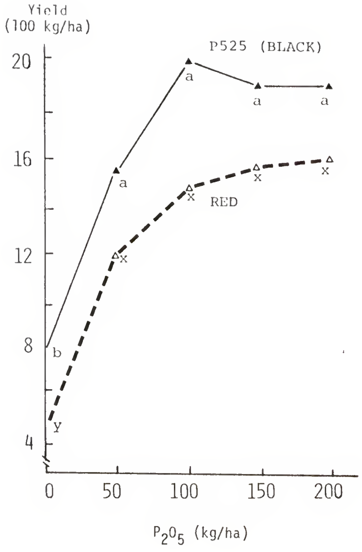


Figure 28. Yield response of two climbing bean varieties to applied phosphorus.

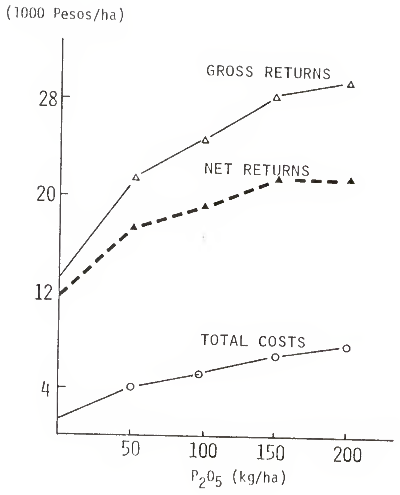


Figure 29. Cumulative costs and returns for fertilization of bush bean.

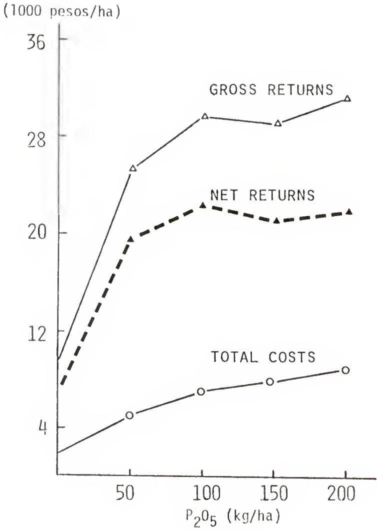


Figure 30. Cumulative costs and returns for fertilization of of climbing bean.

rate for farmer-managed trials averaged over two seasons was 58% of those planted. The results from seven farms are presented in Table 26. As was noted in the previous season, the yields of best CIAT red bush bean varieties were not significantly greater than the commercial bean variety. One of the CIAT climbing bean varieties appeared promising, but to have an immediate effect on commercial bean production in Restrepo, the technological package must have a bush bean basis. Variation in yield and pods per plant among replications was greater with climbing bean than with bush bean types (Table 27).

Population density at harvest was far below recommended seeding rates. Apparently, farmers are reluctant to decrease within-row plant spacings, preferring instead to plant a few extra rows with the remaining seed. Whereas farmers carefully followed planting instructions on row length and between-row spacing, they did not heed instructions on row number. There are several possible explanations. Cultural conditioning, such as the stress on production per plant rather than production per unit land area, may be in conflict with yield maximization thinking. Also small farmers view weed control as the elimination of all weeds present, including those between plants in the row. Manual within-row weeding at high population densities would require hand pulling, which would disturb the rooting system of neighboring plants and would interrupt the rhythm of hoeing. The minimal spacing between plants would therefore be dictated by the width of the hoe blade. Finally, experience may have taught farmers that the low nutrient status of their soil resource may not support high population densities. When farmers were questioned as to why they planted extra rows in the plots, the common reply was that

Table 26. Treatment means from seven Farmer Group Trials (Stage 4).

Treatment	Density	Pl. ht.	Pods/ pl.	Beans/ pod	Yield
	pl/m^2	cm			kg/ha
Bush bean					
P366 + P_2O_5	15.8a	40.6a	4.3a	4.2a	758.7a
P124 + P_2O_5	13.5b	40.7a	4.5a	3.2b	378.6b
Calima + P_2O_5	12.7bc	41.5a	6.0a	3.3ab	830.9a
Calima + Org. Fert.	10.7c	37.2a	6.9a	3.5ab	905.6a
Climbing bean					
P103 + P_2O_5	7.0x	92.1	5.9y	3.7y	460.9y
P220 + P_2O_5	7.0x	218.2	13.2x	6.6x	1087.4x

Numbers in the same column followed by the same letter are not significantly different at the 0.05 level.

Table 27. Coefficients of variation for treatments in seven Farmer Group Trials (Stage 4).

Treatment	Density	Pl. ht.	Pods/ pl.	Beans/ pod	Yield
	----------% C.V.----------				
Bush bean					
P366 + P_2O_5	13.1	20.2	33.3	18.6	38.0
P124 + P_2O_5	17.6	23.0	32.2	11.0	42.5
Calima + P_2O_5	21.9	26.8	33.7	12.9	24.9
Calima + Org. Fert.	19.7	24.7	44.9	20.7	38.7
Climbing Bean					
P103 + P_2O_5	29.7	53.9	66.5	26.0	75.9
S220 + P_2O_5	18.0	29.6	87.2	28.1	66.6

surplus seed had been included in the package, suggesting a failure of communication or a lack of appreciation of the importance of population density.

In order to insure a high adoption potential for the technology under study in these trials, emphasis was placed on risk and cost factors. Four selected red bean varieties were used in the preliminary package for comparison with the local red bush bean variety. This diversification of varieties imitates the risk aversion methods used in traditional technology. The element of risk was also reduced by stressing only a few modifications of the traditional bean technology, such as chemical disease prevention and phosphorus fertilization. Farmers could therefore continue to use their proven and familiar techniques, which include planting at a certain stage of the moon, spacing rows so that weeds can be efficiently controlled by hoeing, and fertilizing with organic materials. Adoption potential is strengthened by innovations that minimize divergence from the norm. There is also a trade-off between attaining impressive yields and enhancing adoption. From a practical standpoint, there was no alternative to the use of low-yielding red bean varieties which had an established market, over a high-yielding black bean variety with a low consumption and a low economic value. Small farmers respond to profit incentives, and avoid technological innovations which require large cash outlays. Like other researchers who had attempted to design small farm technology, the author was faced with the dilemma of maximizing potential economic returns and adoption potential while minimizing changes in the traditional system and the excessive use of expensive agrochemical inputs.

Because of the site specificity of a given technology and yield variability between seasons, a basic core technology was formulated for the Restrepo region and tested by farmers during Stage 4. If successful generally, this minimum technology could then be customized to the specific conditions of each subregion and supplemented with additional inputs according to the economic means and motivations of each farmer. The components of the technology (fertilizer, fungicide, improved varieties, and management recommendations for population density and pest control) were packaged for delivery under the assumption that the effect of the package as a whole would be greater than the average effect of the sum of the individual components. For example, the yield response and profit potential resulting from chemical disease control alone would not be impressive enough in itself to stimulate adoption. However when disease control is complemented by the other inputs (e.g. fertilizer) yield differentials are increased, making the technology more attractive.

Improved varieties are essential to the productivity of such a package. Significant changes in bean yields on small farms can only be accomplished by the introduction of outside inputs and innovations. Since farmers already utilize the resources at their disposal in terms very close to the optimum marginal returns, the farmers' economic position cannot be improved by rearranging the resources that comprise the traditional system. The success of the Green Revolution in increasing rice and wheat productivity can be traced to the introduction of improved high-yielding varieties. The preliminary technological package in this study was therefore crippled by the lack of an improved red bush bean variety. When farmers compared a range of bean colors, representing

the nine basic colors in CIAT bean germplasm, red varieties consistently were preferred (Table 28). Of the other bean colors, white beans ranked third and black beans ranked last.

Economic Evaluation

Bean production enterprise budgets for both bean types are presented in Tables 29-31. While the increase in gross income with Calima resulting from improved technology was proportional to the increase in yields (i.e. 30%), net returns increased 54% over those of traditional technology. Labor costs and cash expenses increased 26% and 8%, respectively. The simulation of farmer technology in replicated trials on four farms and unreplicated experiments on 18 other farms over a period of three seasons resulted in a mean yield of 957 kg/ha, which is slightly higher than both the farmer yields measured in Stage 1 and the national bean production average. Improved technology for Calima and the climbing bean varieties is based on data from eight replicated and 18 non-replicated trials.

Labor requirements used to calculate labor costs in the partial budgeting analyses were based on a separate economic survey of bean production in Restrepo (Varela, 1977) conducted by CIAT at the end of this study. Aside from hired labor, the purchase of fertilizer accounted for the largest single cash expenditure. Since no consideration is made for the utilization of family labor and since an expensive phosphorus fertilizer (Triple Superphosphate) is used in these calculations, net income estimations are conservative. Triple Superphosphate was incorporated in the enterprise budgets because this was the source of

Table 28. Results of Paired Comparison Tests for ranking bean color.

Bean color	Paired Comparison Test†								Total	C.V.	R§
	1	2	3	4	5	6	7	8			
	------------------ Preference frequency							----------		%	
Cream	1	1	2	3	2	2	4	3	19	38	8
Beige	4	6	1	4	4	2	6	4	31	44	4
Brown	3	5	4	2	2	4	2	4	26	36	7
Pink	5	2	3	6	6	1	4	2	29	53	6
Maroon	8	4	8	2	8	7	4	6	47	39	2
Red	6	7	7	8	5	2	8	7	50	32	1
Yellow	0	8	6	0	1	5	3	8	31	87	5
Black	2	0	0	5	0	3	0	0	10	146	9
White	6	3	5	6	7	7	5	3	42	30	3

† Each number represents the number of times each color was preferred over eight other colors.
§ Rank Order

Table 29. Bush bean enterprise budget: Farmer technology.

Item	Unit	Price/ unit	Quantity	Value/ha
		US$		US$
<u>Gross Income</u>				
Beans (14% moisture)	kg	0.61	957.07†	583.81
<u>Cash Expenses</u>				
Seed	kg	0.80	71.90	57.52
Fertilizer (Chicken manure)	kg	0.06	1795.80	107.75
Fungicide (Manzate)	kg	2.14	1.17	2.50
Insecticide (Malathion)	liter	2.46	0.56	1.38
Adherent (Triton)	liter	1.14	0.05	0.06
Transport	trip to Restrepo	0.29	1.00	0.29
Total cash expenses				169.50
<u>Labor Costs</u>				
Land Preparation	man-days/ha	2.00	32.50	65.00
Seeding	man-days/ha	2.00	10.50	21.00
Fertilizer Application	man-days/ha	2.00	7.50	15.00
Pest Control	man-days/ha	2.00	20.80	41.60
Harvest	man-days/ha	2.00	26.00	52.00
Total labor costs				194.60
<u>Net Income</u>				219.71

Calculations are based on an exchange rate of $35 pesos/US$ dollar.
† Mean yield of local bush bean variety (Calima) in monoculture at the farmer level of technology at 22 locations.

Table 30. Bush bean enterprise budget: Improved technology.

Item	Unit	Price/ unit	Quantity	Value/ha
		US$		US$
Gross Income				
Beans (14% moisture)	kg	0.61	1255.81†	766.04
Cash Expenses				
Seed	kg	0.80	100.00	80.00
Fertilizer: Chicken manure	kg	0.60	1000.00	60.00
50 kg P_2O_5	kg	0.27	109.00	29.43
Fungicide: Dithane M45	kg	2.00	1.00	2.00
Koccide	kg	2.60	1.00	2.60
Insecticide (Furadan)	kg	0.30	30.00	9.00
Adherent (Triton)	liter	1.14	0.08	0.09
Transport	trip to Restrepo	0.29	1.00	0.29
Total cash expenses				183.41
Labor Costs				
Land Preparation	man-days/ha	2.00	43.70	87.40
Seeding	man-days/ha	2.00	12.20	24.40
Fertilizer Application	man-days/ha	2.00	9.40	18.80
Pest Control	man-days/ha	2.00	26.50	53.00
Harvest	man-days/ha	2.00	30.70	61.40
Total labor costs				245.00
Net Income				337.63

Calculations are based on an exchange rate of $35 pesos/US$ dollar.
† Mean yield of Calima at improved level of technology in monoculture from 26 locations.

Table 31. Climbing bean enterprise budget: Improved technology

Item	Unit	Price/ unit	Quantity/ ha	Value/ha
		US$		US$
Gross Income				
Beans (14% moisture)	kg	0.50	1419.20†	709.60
Cash Expenses				
Seed	kg	0.57	44.50	25.37
Fertilizer: Chicken manure	kg	0.06	1000.00	60.00
50 kg P_2O_5	kg	0.27	109.00	29.43
Fungicide: Dithane	kg	2.00	1.00	2.00
Koccide	kg	2.60	1.00	2.60
Insecticide (Furadan)	kg	0.20	15.00	4.50
Adherent (Triton)	liter	1.14	0.08	0.09
Transport	trip to Restrepo	0.29	1.00	0.29
Total cash expense				124.28
Labor Cost				
Land Preparation	man-days/ha	2.00	43.70	87.40
Seeding	man-days/ha	2.00	12.20	24.40
Fertilizer Application	man-days/ha	2.00	9.40	18.80
Support Installation	man-days/ha	2.00	10.00	20.00
Pest Control	man-days/ha	2.00	26.50	53.00
Harvest	man-days/ha	2.00	30.70	61.40
Total labor cost				265.00
Net Income				320.32

Calculations are based on an exchange rate of $35/US$ dollar.

† Mean yield of all CIAT climbing varieties at improved level of technology in monoculture at 26 locations.

phosphorus used to attain the reported yields. Other lower analysis and less soluble phosphorus sources, such as simple superphosphate, basic slag (*Escorias Tomas*), and rock phosphate (*Fosforita Huila*), are occasionally available in the region, but the supply is not dependable because these products are not included in the inventory of the Coffee Federation Cooperative. Rock phosphate is most effective on very acidic soils, whose pH levels are lower than those commonly found in the Restrepo region. Basic slag, which is a by-product of the iron mines in the Department of Boyaca, adversely affects boron availability. Transportation of both rock phosphate and basic slag to small farm fields in Restrepo is expensive and difficult, and a separate campaign to validate and demonstrate these slow release phosphorus sources on small farms would be required before they could be considered for recommendation. It should be noted however that the price of chemical fertilizers in the project area have not increased as rapidly as those of organic fertilizer (Table 32), suggesting that Restrepo's small farmers may rely more heavily on chemical fertilizers in the future.

Table 32. Input price differential between May 1976-June 1977 (Restrepo, Colombia).

Product	Price		Percentage Increase
	May 1976	June 1977	
	------- $ pesos/kg---------		%
Fertilizer			
Chicken manure	0.61	2.00	228
Rock phosphate from Huila	1.70	1.80	6
Simple Superphosphate	2.75	2.84	3
Triple Superphosphate	9.19	9.50	3
13-26-4	8.14	8.56	5
14-14-14	7.04	7.56	7
Fungicide			
Dithane 45	59.75	70.00	17
Manzate	56.40	75.00	33
Insecticide			
Furadan	10.24	10.40	2
Diostop	114.95/liter	130.70/liter	14
Adherent			
Triton	28.75/liter	40.00/liter	39

SUMMARY AND CONCLUSIONS

A 22-month study was conducted in a coffee-growing region of Colombia to evaluate a methodology for the design and transfer of agronomic technology to increase bean productivity on small farms. The project region centered on the town of Restrepo, which is 58 kilometers from Cali, and included 16 surrounding villages. Approximately 65% of the farms in this region were less than 10 hectares in size, and the altitude ranged from 1,200 to 1,600 meters above sea level. The bimodal rainfall pattern permitted two growing seasons per year, and the study was therefore sub-divided into four stages, each corresponding to a growing season.

The objective of the methodology was the development of a low-cost, low-risk technological package for bean production on small coffee farms. This involved screening promising bean varieties selected from the CIAT germplasm collection for productivity and yield stability, quantifying the limiting factors in the production environment, and determining the profitability of the final integrated technology at the farm level. Unlike most agronomic studies which emphasize yield maximization, the goal of this study was to increase economic returns without incurring excessive risk. This implies a minimum input strategy which emphasizes the adoption potential rather than the yield potential of the technology.

In the initial observation stage an effort was made to establish credibility with local farmers and extension personnel, while at the

same time to understand the traditional production system and the regional crop production infrastructure. Information was obtained on the local bean varieties, the small farm resource base, climatic conditions, and labor utilization patterns. The predominance of coffee production over other economic enterprises indicated that even small farmers in the Restrepo region had been exposed to credit and input management and were familiar with commercial decision-making. Overall the farmers appeared interested in trying new methods, particularly those dealing with low yielding food crops. Coffee Federation personnel also showed interest in the improvement of bean productivity as part of their diversification program, because beans were both a cash and food crop in the region and because bush beans were an ideal intercrop for coffee during the establishment phase.

Local bean varieties had some susceptibility to diseases, but they seemed to produce well over a wide range of microclimatic and edaphic conditions. Population densities for bush bean were approximately one-half the recommended density. Local bush bean yields were under 1,000 kg/ha, and storage losses due to insects motivated small farmers to sell all their produce at the end of the season when prices were low. Although climbing bean varieties are grown throughout the Valle Department for the production of green beans (immature pods), dry bean production from indeterminate Type IV varieties has not reached the level of commercial importance as in other small farm regions of the country (i.e. Antioquia and Narino). Therefore, local preferences were stronger for bush bean types, which had an established market and which associated with coffee without excessive competition for light, nutrients, space, and labor. The majority of the CIAT high-yield-potential

varieties available for use in this study were black-seeded, while market prices favored large red-seeded varieties.

Since acreage available for field crop experimentation on small farms is limited, sampling procedure was analyzed in a nine variety bush bean and a nine variety climbing bean trial to determine the minimal plot and sample sizes. Plots with a minimum of 10 meters of row were found to be optimum for the determination of population density, while differences among the coefficients of variation for sample sizes used to estimate the number of pods per plant and the number of beans per pod were not significantly different. Yield adjustments for variations in population density at harvest in the variety screening trials were not necessary, because regression analyses of yield on density revealed that variations in yield were attributable to random variation rather than variations in density. Stage 2 trials demonstrated the potential for increasing bean productivity on small farms through the combined use of improved varieties at optimum population densities and low levels of selected agro-chemical inputs. Maximum yields of 2,458 kg/ha and 1,570 kg/ha were attained in monoculture stands of bush and climbing bean types, respectively. The average yield for nine bush bean varieties at four locations and two technology levels was 1,363 kg/ha. Yields were suppressed 40% when beans were grown with maize. Black bean yields were 90% greater than red bean yields in bush types and 176% greater in climbing bean types. CIAT promising varieties showed a much greater yield stability over a range of environmental conditions than did the local bean varieties. There was also evidence that local varieties were selected specifically

for unfavorable production conditions and were unresponsive to improved conditions, such as those derived from the utilization of new technology. While there was a highly significant genotype by location interaction, genotype by planting system and genotype by technology interactions were not significant. This implies that varietal selection for small farm technology can occur in monoculture at high input levels.

Results of the Stage 3 experiments showed that local bean yields are limited by planting density, soil fertility, and diseases. Variation in rainfall between seasons is the primary source of risk in the traditional production system and may explain the significant genotype by season interaction. Drought tolerance should be given a high priority in germplasm improvement for small farm production. Efforts to select high-yielding varieties with color and appearance characteristics similar to those of the local bush bean variety were not successful. Since the philosophy of small farm development projects should emphasize the adoption potential rather than the yield potential of improved technology, the technology evaluated in the final stage of this study did not include an improved variety in spite of the existence of several high-yielding black-seeded varieties. Nevertheless, agrochemical inputs selected to overcome limiting factors in the production environment and optimum plant density recommendations did increase yields (30%) and net income (54%) over those of the traditional system. When high-yielding red-bean varieties become available in the near future, as a result of CIAT's intensive germplasm improvement program, further expansions in the productivity and profitability of bean production on small farms can be anticipated.
In addition, Stage 4 experiments indicated that phosphorus fertilization

levels (50 kg P_2O_5/ha) used throughout this study were well below agronomic and economic optimum levels (100 kg P_2O_5/ha). Consequently, farmers who are willing and financially able to invest in the purchase of additional phosphorus fertilizer can expect even greater benefits than those implied in the economic evaluation of improved technology in this study.

While the results of farmer-managed trials which had a success rate of only 58% were inconclusive from the research standpoint, they were invaluable in establishing credibility with small farmers, stimulating interest in the improvement of bean yields, and obtaining insights into the factors limiting production in the traditional farming system. At the same time these Farmer Group Trials allowed the multi-location testing of varieties and improved technology. The research cost was infinitesimal in comparison to the information, ideas, and opinions received and the knowledge shared. Farmer group demonstrations were much more efficient in convincing farmers of the value of an innovation than were conventional field-day audio-visual presentations.

If economic development is to proceed in an environment of social and political stability, attention must be given to the productivity of the small farm sector and the well-being of the rural mass of peasant farmers. This study offers a simple methodology for formulating technological packages for small farm production. The methodology can serve as a viable addition to other development approaches or as a model for the creation of a small farm development project. Critical components of the methodology include on-farm trials, farmer participation, and inter-institutional collaboration in the validation of existing technology.

Validation is the mutual responsibility of both research and extension personnel because it provides the feedback essential to the design of appropriate, acceptable, and economically viable technology for the low income, small scale producer. Such technology must offer a significant economic incentive under the existing price and marketing structure if it is to stimulate adoption by small farmers. It is for this reason that wider and more rapid successes have been experienced with technology for cash crops. The implication from the standpoint of food production in less-developed countries is that the commercialization of small farms is inevitable. The persistent poverty of the small farm sector of these countries, which is perpetuated by "low level equilibrium farming" (Andrews and Kassam, 1977), can no longer be casually dismissed as a problem which will take care of itself. It can only be overcome by a commitment on the part of national planners to invest financial and material resources in the design and implementation of small farm technology to involve small farmers more directly in the larger capitalistic system.

Small farmers use different planting dates, genotypes, fertilizer formulations, pest control methods, and planting systems than those used on research stations. Even without environmental considerations, it is not surprising that research station recommendations have not been appropriate for small farms. Research philosophy must be restructured to deal with specific problems and economic decision-making criteria of the small farmer. Until now, the emphasis has been on yield maximization. Experiments have been conducted to discover the fertilizer, pesticide, and management levels required for highest yields without regard for practicality. What are the optimum levels

of agro-chemical input for small farmers to realize maximum return on investment? What soil amendments and pesticide recommendations are optimal for the myriad of small farm cropping systems? How can production resources, such as the distribution of disease-free seed, be reorganized to meet the needs of the small farm sector? The answers to these questions will require additional multidisciplinary study. Agronomists may have to consider economic factors. Plant breeders may have to understand the anthropological basis of food preference and the ecological interactions of multiple cropping. The approaches to the small farm problem may be as unconventional as the problem is complex.

APPENDIX A-1

FARMER SURVEY (STAGE I)

I. Identification: Settlement____________________ Date__________

Farmer_________________________ Altitude______________

II. Land Tenure and Land Use

1. Is this farm yours or under what conditions do you farm it? (own, rent, share crop, INCORA land recipient, etc.).

2. What is the size of your farm? _____has.

3. How many persons live on the farm?______

4. How is the land distributed?

coffee _____has. (monoculture or intercrop with____________)

maize ____ has. (monoculture or intercrop with ___________)

bean ____ has. (monoculture or intercrop with __________)

yuca ____ has. (monoculture or intercrop with ___________)

banana _____has. (monoculture or intercrop with ___________)

arracacha___has. (monoculture or intercrop with ___________)

pasture ____has.

forest _____has.

other_______has.

5. What is the product or activity which gives the most profit per unit of land area?____________________________

6. What is the product or activity with the most risk (danger)? Why? ____

7. How many years have you produced beans?___________________

8. Do you produce beans every year or only some years? Which season?____

9. The first time that you planted beans, what land area did you plant?____

Appendix A-2

10. What is your purpose in planting beans? (for food, for profit, tradition or custom, for security)____________

III. Rainfall:

11. Which are the months of most and least rainfall?_________

12. Do you use irrigation? With which crops?________________

IV. Description of Labor and Input Usage.

13. How many people do you employ on the farm?

    Family_____________

    Temporary laborers_____

    Permanent laborers_____

14. When you are not working on the farm, how do you use your time? (day labor, business, other). How many days per year?____

15. In which month are you accustomed to planting bean? Maize?

16. Which varieties do you plant?__________________________

17. Are you accustomed to planting by phases of the moon?______

18. Do you mound up, throw away, burn or leave the weeds on the ground before planting?______________________________

19. Do you plant your beans at random or in rows?_____________

20. Is your bean seed from previous harvests on your farm or is it purchased?____

21. Do you use chemical fertilizers in bean production? Maize production? Which formulas? _________________________

22. If you are not accustomed to using chemical fertilizers, why? (very expensive, can't get them, they are difficult to transport)____

23. How often do you weed your stand of beans? Maize? ________

24. Which pesticides do you use for beans? Maize?_____________

25. How many fumigations are required for beans? Maize?________

Appendix A-3

26. What is the major problem in bean production? (lack of technical assistance, lack of credit, poor soils, insects, diseases, lack of market, lack or excess rainfall)_____

27. Is there a bean price variation between seasons? Do maize prices also fluctuate?_____

28. In which months were the prices high? Low?_____

29. Do you store your beans after harvest? Do you also store maize?

30. Have you obtained credit for bean production before? Do you have credit now? For which crops?_____

31. How much time is there between seeding and harvest for beans? Maize?_____

32. Where do you sell your bean harvest? Maize?_____

33. What method of transport to market do you use? How much does it cost? _____

34. Do you buy inputs? Where?_____

35. Would you like to produce more bean and maize? _____

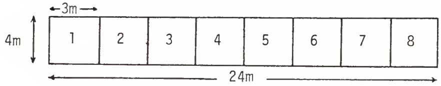
APPENDIX B
EXPERIMENTAL DESIGN FOR MULTILOCATION LIMITING FACTOR TRIALS

Objective: To determine the order of importance of the agronomic bean production factors for each locality.

Design: 1 rep/site (each trial constitutes one rep of the overall regional experiment)

8 treatments with 1 trt/plot

Plot Size: 3 x 4 m = 12 m^2 (9 m^2 experimental area)



Plot	Treatment	Variety		Density		Fertilization†		Insect Control§		Disease Control¶
1	Complete (C)	Tui (black)	+	25.0	+	13-26-4 & Organic	+	Insecticide	+	Fungicide
2	C-Variety	Calima (red)	+	25.0	+	13-26-4 & Organic	+	Insecticide	+	Fungicide
3	C-Density	Tui (black)	+	12.5	+	12-26-4 & Organic	+	Insecticide	+	Fungicide
4	C-(13-26-4)	Tui (black)	+	25.0	+	Organic	+	Insecticide	+	Fungicide
5	C-Organic	Tui (black)	+	25.0	+	13-26-4	+	Insecticide	+	Fungicide
6	C-Insect Cont.	Tui (black)	+	25.0	+	13-26-4 & Organic			+	Fungicide
7	C-Disease Cont.	Tui (black)	+	25.0	+	13-26-4 & Organic	+	Insecticide		
8	Farmer Tech.	Calima (red)	+	12.5	+	Organic			+	Fungicide

† Chemical fertilizer will be applied at rate of 200 kg/ha (organic fertilizer @ 2 ton/ha)
§ Systemic insecticide (Furadan) applied at planting
¶ Four applications of Dithane M45 and Koccide at 12, 25, 35, 45 days after planting.

APPENDIX C
FARMER GROUP TRIALS (1977A)

Objectives: 1) To compare the promising red-bean bush and climbing varieties with the local bush bean variety (Calima) throughout the region.

2) To determine if the promising red-bean varieties and applied phosphorus are more profitable than Calima with the same applied phosphorus or with organic fertilizer.

Experimental Design: One block with six plots.
Each plot will have 3 x 4 meters (12 m^2)
(6 plots x 12 m^2/plot = 72 m^2/trial)
Planting will be in rows with 60 cm between rows for bush bean varieties (5 rows/plot) and one meter between rows for climbing bean varieties (3 rows/plot).
Fumigate at 15, 25, 35, and 45 days after planting.
Use one of the enclosed plastic bags of Dithane M45 in one-half tank (back sprayer) of water for each application.

1	2	3	4	5	6

Plot 1 = P366 + 1 bag of Triple Superphosphate
Plot 2 = P124 + 1 bag of Triple Superphosphate
Plot 3 = Calima + 1 bag of Triple Superphosphate
Plot 4 = Calima + chicken manure (traditional rates)
Plot 5 = P103 + 1 bag of Triple Superphosphate
Plot 6 = S220 + 1 bag of Triple Superphosphate

Summary of the trial: 6 plots (3 x 4 meters) < 4 plots of bush bean (5 rows/plot); 2 plots of climbing bean (3 rows/plot)

All plots will have Triple Superphosphate with the exception of one plot of Calima, which will have chicken manure. This plot will be called the "check" and will otherwise be seeded and fumigated in the same manner as the others.
Spray all plots evenly during the four applications of fungicide.
Weed as necessary.

APPENDIX D
RESULTS OF 25 SOIL ANALYSES

	Location	pH	O.M.	P¶	Fe	Mn	Zn¶	B¶	K¶
			%	ppm	ppm	ppm	ppm	ppm	meq/100 g
1.	Agualinda	5.6	7.7	7.3†	---	42.0	3.5	0.33†	0.78
2.	Agrado	6.2	8.3	11.5†	---	26.0	7.4	0.34†	2.18
3.	Aguamona	6.0	9.1	1.2†	3.42	18.1	2.1	0.17†	1.65
4.	Alto del Oso	5.5	6.9	2.3†	56.00	57.7	33.6	0.27†	0.36
5.	Alto del Oso	5.4	11.7	3.0†	---	---	0.5†	0.28†	---
6.	Cachimbal	5.3	3.9	1.2†	---	---	5.5	0.32†	---
7.	Caimital	5.6	4.0	2.2†	---	---	1.8§	0.48	---
8.	Calimita	5.4	8.4	1.6†	---	10.0	0.8†	0.25†	1.34
9.	Calimita	5.6	8.7	11.0†	---	24.0	2.8	0.42	0.74
10.	Concentracion J.M.	5.5	3.8	2.3†	50.3	62.4	1.6§	0.20†	0.11†
11.	Concentracion J.M.	5.9	2.7	0.6†	81.9	56.0	2.9	0.20†	0.11†
12.	El Dorado	5.9	6.4	3.6†	5.2	85.7	6.9	0.08†	0.14†
13.	El Dorado	6.0	7.4	1.4†	3.2	74.6	2.3	0.18†	0.17§
14.	El Dorado	5.5	6.9	2.3†	56.0	57.7	33.6	0.20†	0.36
15.	El Tambor	6.0	3.4	3.6†	37.4	61.7	5.1	0.20†	0.27
16.	Miravalle	5.7	5.9	3.7†	---	---	3.4	0.44	---
17.	Porvenir	5.4	3.8	1.0†	33.9	53.7	3.3	0.09†	0.26
18.	Porvenir	5.4	2.9	5.5†	---	---	2.7	0.21†	---
19.	Porvenir	5.6	7.3	13.8†	---	63.0	3.2	0.26†	1.44
20.	Sabaletas	5.6	15.1	0.8†	3.4	23.2	1.5†	0.12†	0.55
21.	Sabaletas	5.8	12.5	1.1†	---	---	0.5†	0.57	0.42
22.	Sabaletas	5.4	11.9	1.9†	---	---	1.5†	0.64	0.65
23.	Sabaletas	5.4	12.0	0.3†	---	---	0.8†	0.56	0.47
24.	San Salvador	6.4	5.5	2.1†	---	41.0	3.5	0.20†	0.64
25.	Villamaria	5.9	3.7	0.8†	---	---	2.7	0.16†	---

† Denotes deficiency; § Very low level but not within the deficiency range; ¶ All 25 soil samples showed a strong deficiency in phosphorus. In addition, 76% were deficient in boron, 24% in zinc, and 12% in potassium.

APPENDIX E
PAIRED COMPARISON TEST FOR BEAN COLOR

Farmer *Abelardo Gomez*

Settlement *Agualinda*

Date *March 3, 1977*

Bean preference *bush*

Rank order for size:

1. *large*
2. *medium*
3. *small*

	A Cream	B Beige	C Brown	D Pink	E Maroon	F Red	G Yellow	H Black	I White
Cream A		B	A	D	E	F	B	A	I
Beige B			B	D	E	F	B	B	I
Brown C				D	E	F	C	C	I
Pink D					E	F	D	D	D
Maroon E						F	E	E	E
Red F							F	F	F
Yellow G								G	I
Black - H									I
White I									

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BIOGRAPHICAL SKETCH

Robert Earl Hudgens was born on May 2, 1945, in Oakland, California. In June 1962, he graduated from Pacific High School in San Leandro, California, where he had been active in student government, athletics, and journalism. In June 1967, he received the Bachelor of Science degree in International Agricultural Development from the University of California at Davis.

He joined the Peace Corps in August of 1967 and worked for three years in Bolivia, gaining valuable experience in the Latin American culture, language and rural development. He taught sheep shearing and management for one season in villages around Cochabamba, and then transferred to the colonization and resettlement programs in the Chapare and Alto Beni regions of the eastern Andes.

Upon completion of his assignment, he returned to the United States by land and entered the University of Florida in January 1971. With funding from the Center for Tropical Agriculture and the *Instituto Nacional de Investigaciones Agropecuarias* (INIAP), he returned to South America in March 1972 and conducted thesis research for one year at the Pichilingue Experimental Station on the coast of Ecuador. In August 1973, he received the Master of Science in Agriculture degree.

He re-enrolled in the University of Florida in January 1974 to continue studies toward the Doctor of Philosophy degree with a major in agronomy and a minor in Latin American Studies. Dissertation research was conducted from September 1975 to July 1977 in a mountainous coffee growing region of Colombia near the *Centro Internacional de Agricultura Tropical* (CIAT).

Mr. Hudgens is a member of the American Society of Agronomy, the Crop Science Society of America, and the Alpha Zeta honorary fraternity. He is happily married to the former Barbara Lea Ritchason.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Darell E. McCloud, Chairman
Professor of Agronomy

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